...erial No. 215

DEPARTMENT OF COMMERCE

U. S. COAST AND GEODETIC SURVEY

E. LESTER JONES, DIRECTOR

TERRESTRIAL MAGNETISM

MAGNETIC DECLINATION IN THE UNITED STATES FOR JANUARY 1, 1920

By

DANIEL L. HAZARD
Assistant Chief, Division of Terrestrial Magnetism

Special Publication No. 90

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CONTENTS.

INTRODUCTION.

The magnetic work of the United States Coast and Geodetic Survey, begun as one of the essential parts of the preparation of nautical charts of the coastal waters, has been extended to cover the interior of the country to meet the needs of the surveyor. Nearly all of the early land surveys in the United States were made by compass and the boundaries in the deeds were defined by compass bearings, and in many localities and for certain kinds of surveying (especially the retracing of the lines of old compass surveys) the compass is still in use. The compass does not, in general, point true north nor is its direction at any place constant, hence knowledge of the compass variation (magnetic declination), and its changes, is required by those who make use of the compass. The object of this publication is to supply that information for the United States. The distribution of the magnetic declination and its annual rate of change for the beginning of 1920 are shown graphically on an isogonic chart. The secular change of the declination since 1750, or the date of the earliest observations, is given in tabular form for one or more places in each State. Tables are given also to show the manner in which the declination changes in the course of the day, the so-called diurnal variation.

Methods of determining the true meridian are explained, so that the surveyor may determine the magnetic declination for himself at places where there is no meridian line or other true bearings available.

As there is much confusion in the use of the word "variation," the following notation will be adhered to in this publication.

Magnetic declination is the angle between the true north and the magnetic north and is considered east or west according as the compass needle points east or west of true north.

Secular change of the magnetic declination is the change extending over a long period of years.

Annual change is the amount of secular change in one year.

Diurnal variation is the change in declination in the course of a day. While this change is usually not taken into account in compass surveys, its effect may be considerable, as will be seen from a concrete example. If a line a mile long was run about 8 o'clock in the morning and again about 2 o'clock in the afternoon, using the same starting point and the same compass bearing in each case, the terminal points of the two lines might be 20 feet or more apart because of the change in the direction of the compass needle during the day.

The secular change of declination appears to be periodic in character; that is, it does not go on indefinitely in one direction. Eventually a turning point is reached and a change in the opposite direction sets in. Several centuries are required for its full development, a period longer than is covered by reliable observations. In the United States we have record of one turning point, as shown in the secular change tables, and at some stations, for which there is a long series of observations, there are indications of a second. The rate of change is quite irregular, so that we can not predict much in advance what the change will be. On this account secular change tables must be revised and brought up to date as new information becomes available, and it is the practice of this bureau to issue a new isogonic chart and new tables every five years.

Special Publication No. 33, issued in 1915, contained an isogonic chart for 1915 and secular change tables based on the results to June 30, 1915. In the second edition, published in 1920, the values of annual change for extending the tables beyond 1915 were improved as the result of additional observations at repeat stations, but the information available at that time was not sufficient to warrant the construction of an isogonic chart for 1920. Repeat stations have now been occupied in all parts of the country since 1915, so that the secular change up to 1920 is well established and a fair estimate can be made of the rate of change since that year.

AVAILABLE DATA.

For the construction of the isogonic chart values of the magnetic declination at over 5,000 places in the United States and about 1,000 places in Canada, Mexico, and the West Indies were available. For the extension of the isogonic lines over adjacent waters, use has been made of the results obtained on the vessels of this bureau and on the *Carnegie* of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

In the prosecution of the magnetic survey of the United States observations have been made by this bureau at nearly every county seat and at many other places. At most of the stations a stone or other durable marker was placed and the true bearings of several prominent objects were determined, so that they might be available for future use. With changing local conditions either the marker or the objects have no doubt disappeared in many cases, but most of them should still be available, and descriptions of the stations in any particular locality can be obtained from this office by anyone desiring to make use of them.

The results of magnetic observations made by this bureau up to the end of 1915, together with corresponding reduced values for January 1, 1915, are given in Special Publication No. 44. Later results have been published annually as Special Publications 42, 51, 55, 64, 72, and 87.

In addition to the work of this bureau, use has been made of results of recognized accuracy obtained by others in this country, Canada, Mexico, Central America, and the West Indies. The numerous results in Canada are contained in two recent publications, viz, Magnetic Observations in Western Canada (Bulletin No. 46, topographic survey branch, Department of the Interior) and Magnetic Results, 1907–1920, by C. A. French (Publications of the Dominion Observatory, Vol. V, No. 5). The secular change data contained in these publications has been of great assistance in fixing the position and direction of the lines of equal annual change of declination along our northern border.

The distribution of magnetic stations in the United States corresponds, roughly, to the distribution of population, the stations being closer together in the more thickly settled portions of the country.

CONSTRUCTION OF ISOGONIC CHART.

It is customary to represent graphically the results of a magnetic survey by means of isomagnetic charts; that is, maps on which lines are drawn through places where the values of a particular magnetic element are the same. In the case of the magnetic declination, the map showing the lines of equal magnetic declination is called an isogonic chart. In the preparation of such a chart all of the observed values must be reduced to the same epoch by means of the secular change data derived from the observations at "repeat" stations. The reduced values are then plotted on a map and the lines of equal magnetic declination are drawn to conform to the plotted values. Because of the prevalence of local disturbance this process generally becomes more and more difficult as the number of stations in a given area increases, and in greatly disturbed regions the sinuosities of the lines are an indication of disturbance rather than an accurate representation of the distribution. In some regions it is impossible to represent the large local disturbances by continuous lines, but a disturbed area of limited extent may be represented by a small closed curve and isolated abnormal values can be given on the chart.

In general there are very few values which are exactly the amount selected for a particular line—for example, there are very few stations at which the reduced declination is exactly 6° East—so that the location of the line must depend largely upon interpolation between values a little larger and a little smaller than the selected amount. At first sight it would appear that a particular line should be drawn so that all greater plotted values will fall on one side and all smaller values on the other. A little consideration will show, however, that this method will not give the best representation of all the data. The aim should be to draw the lines in such a way that the average difference between the plotted values and corresponding values obtained by interpolation between the lines will be a minimum.

The method outlined above was followed in preparing the isogonic chart for 1915. In the case of the 1920 chart it was not considered

necessary to go to the trouble of reducing the individual results to January 1, 1920. The results for new stations occupied since 1915 were reduced to 1915 and plotted on the map used in the construction of the 1915 chart. The change of declination between 1915 and 1920 in all parts of the country was derived from the accumulated secular change data and then the isogonic lines for 1920 were drawn on the basis of the 1915 values, making allowance for the change in the five-year interval. For example, in a region where east declination had decreased 0°.3 between 1915 and 1920, the line for 6° east was drawn as 6°.3 east for 1915. In general, this process involved simply a shift of the 1915 lines to the east or west by an amount representing the change of declination in the interval. In some places, however, changes were made as a result of additional observations or to better represent the old ones.

LINES OF EQUAL ANNUAL CHANGE.

The lines of equal annual change of declination, shown in blue on the chart, are based largely on observations made at repeat stations since 1918. Because of the varying character of the secular change during the past few years, the derivation of these lines was unusually difficult for the western part of the country, but as drawn they represent fairly well the rate of change of declination in January, 1920, and give the best values of the rate of change since that date now available. As additional repeat observations are made it will be possible to derive improved values. There has been a marked change in the position of the lines since 1915 and further change is to be expected. The following table, based on the continuous record at the magnetic observatories specified, shows how irregular the rate of change of declination has been since 1910:

Change of declination at observatories.

Year.	Vieques, P. R.	Cheltenham, Md.	Tucson, Ariz.	Toronto, Canada.	Sitka, Alaska.
	° ′	° ′	° ′	° ′	° ′
1910	2 20.6 W.	5 41.4 W.	13 25.8 E.	6 03.9 W.	30 16.4 E.
1911	29.9	45.6	29.7	09.0	19.1
1912	39.0	50.0	33.5	13.7	20.9
1913	2 49.6	54.6	37.0	18.4	22.0
1914	3 00.4	5 59.8	39.9	23.8	22.9
1915	10.1	6 04.0	42.5	28.5	23.2
1916	19.2	07.7	44.4	33.4	23.9
1917	27.0	10.4	46.1	36.2	24.7
1918	34.0	12.4	47.1	38.3	24.9
1919	40.0	15.0	47.8	41.0	26.9
1920	46.2	18.5	48.0	45.4	28.5
1921	3 53.3	6 22.4	13 47.8	6 50.9	30 28.7

The north end of the compass needle is moving to the westward at all places east of the line of no annual change and to the eastward at all places west of that line.

In the part of the United States east of the line of no declination (agonic line) west declination is increasing at an annual rate of from 1 to 4 minutes.

In the large region between the agonic line and the line of no annual change east declination is decreasing at an annual rate of from 0 to 4 minutes.

In the region south of the line of no annual change east declination is increasing at an annual rate of 0 to 2 minutes.

ACCURACY OF THE ISOGONIC CHART.

From what has been said regarding the construction of the isogonic chart it will be seen that a close representation of the observed values is possible only when they are few in number or in a region free from local disturbance. Isolated values differing by as much as 1° from the value for the same place derived from the isogonic lines are given on the chart. There are a considerable number of values not shown which differ by nearly that amount and a difference as great as half a degree is not infrequent, even where the isogonic lines do not appear very irregular. The declination at a place where observations have not yet been made may differ from the chart value for that place by as much as any observed value in that general region.

SECULAR CHANGE TABLES.

On the succeeding pages will be found tables showing the secular change of the magnetic declination for one or more places in each State from 1750, or the date of the earliest observations, to 1920. They are based on similar tables which accompanied the isogonic chart for 1915 in Special Publication No. 33, with only such modifications as were needed to extend them to 1920 and represent more closely the secular change since 1900 as affected by later information.

While it is possible that the secular change of declination is affected somewhat by local conditions—for example, by the presence of local disturbance—our observational data are not as yet sufficiently extensive or detailed to permit more than an approximate representation of average conditions. There are very few stations for which we have accurate results as early as 1850, and it has not been possible as a rule to make observations at the exact spot at which the early observations were made. Even in recent years, when magnetic stations have been selected with particular reference to their future availability, it often happens that the observer finds a station no longer suitable for use when he goes to reoccupy it after the lapse of 5 to 10 years.

The general features of the secular change appear to vary with comparative uniformity in passing across the country, and this has been the fundamental idea in deriving a homogeneous set of tables from more or less heterogeneous data. The results at all the repeat stations in a limited region were combined to obtain a table of values representing approximately the average secular change for that region. This table was compared with similar tables for adjoining regions and a general smoothing out of inconsistencies was made. From these tables other similar tables were derived by interpolation for a greater number of smaller areas for which it was intended to publish secular change tables. From these tables, in turn, others were prepared showing the change of declination at 5 or 10 year intervals at some place near the center of each area, at which recent observations had been made.

From this it will be seen that while a table gives *directly* the declination at different times for but one place in a specified region, it

represents with almost the same accuracy the *change* in declination at any place in the limited area to which the table refers. For a place lying near the border of the specified region a somewhat better result may be obtained by interpolating between the tables for that region and the adjoining one, as explained in example 2 given below.

USE OF SECULAR CHANGE TABLES.

Whenever a surveyor is called upon to redetermine the boundary lines of a tract of land run out by compass at some previous date and can find in the vicinity a well-defined line known to have been established with the same compass at about the same time as the lines of the tract in question, he can not do better than determine the amount of change in the compass bearing of that well-defined line and use it to obtain the present bearings of the boundary lines to be reestablished. In this way he will eliminate possible errors in the two compasses used. Only in the absence of such definite information is the use of the following tables recommended.

In using these tables the surveyor must bear in mind the uncertainties incident to the use of the compass and should not be surprised if, for example, the change in declination since the early part of the nineteenth century, as given by the tables, differs by half a degree or even more from the value indicated by his own retracing of old lines. Even at the present time some compasses are in error by as much as a quarter of a degree, owing to imperfect construction or lack of proper care, and 100 years ago the state of affairs was still worse. The tables are intended to give the actual change in the magnetic declination, eliminating as far as possible the errors of individual instruments, but they are only approximate and the earlier portions are less reliable on account of the inferior character and limited amount of data on which they are based.

The figures on any line of the tables refer to the 1st day of January of the year given in the first column. A value for any other date must be obtained by interpolation from the tabular quantities. In this operation it is convenient to express the month and day as a fraction of the year, as follows:

Jan. 19 to Feb. 24=0.1	July 21 to Aug. 25=0.6
Feb. 25 to Apr. 1=0.2	Aug. 26 to Oct. 1=0.7
Apr. 2 to May 8=0.3	Oct. 2 to Nov. 7=0.8
May 9 to June 13=0.4	Nov. 8 to Dec. 13=0.9
June 14 to July 20=0.5	Dec. 14 to Dec. 31=1.0

While, as has been shown in the introduction, the rate of change is not constant for even a period of five years, it is accurate enough for all practical purposes to assume that the annual change is uniform for the intervals between the tabular values.

The use of the tables may be best explained by a few examples.

1. What was the change in declination in eastern Alabama between June 1, 1795, and August 10, 1920?

In the table for Ashland, eastern Alabama, the values for 1790 and 1800 are 5° 32′ E., and 5° 53′ E., respectively, showing an average annual increase of 2′.1. Hence the value for June 1, 1795, would be 5° 32′ E. + (2′.1 × 5.4) = 5° 43′ E. The table gives for 1920 the value 3° 00′ E. with an annual change of 0′.0. Hence the value for

August 10, 1920, would be 3° 00′ E. Therefore the north end of the compass needle pointed 2° 43′ more to the east on June 1, 1790, than it did on August 10, 1920.

2. The magnetic declination at New Castle, Pa., on November 15, 1902, was 2° 55′ W. What was it at the same place in January, 1810?

New Castle lies near the boundary between Pennsylvania and Ohio. From the table for western Pennsylvania are derived the values 0° 38′ E. for January, 1810, and 4° 05′ W. for November, 1902, showing a change of 4° 43′ in the interval. The corresponding values for eastern Ohio are 2° 16′ E. and 2° 06′ W., showing a change of 4° 22′. The mean of these two values, 4° 43′ and 4° 22′ applies to New Castle. Hence the needle pointed 4° 33′ more to the east at New Castle in January, 1810, than it did in November, 1902, and the declination at the earlier date was 1° 38′ E.

3. A four-sided piece of land at Santa Barbara, Calif., was surveyed in February, 1831, and the bearings recorded as follows: N. 20° 15′ W., N. 75° 30′ E., S. 18° 45′ E., and S. 78° 00′ W. What bearings should be used in order to retrace the lines in March, 1917?

From the table for California south, Mojave, the value for February, 1831, is 13° 23′ E. and for March, 1917, 16° 08′ E., showing an increase of 2° 45′ in the interval. The desired bearings are, therefore, N. 23° 00′ W., N. 72° 45′ E., S. 21° 30′ E., and S. 75° 15′ W.

Secular change of the magnetic declination in the United States.

Region.	Ala., east.	Ala., west.	Ariz., east.	Ariz., west.	Ark., east.	Ark., west.	Calif., southeast.	Calif., south.	Calif., middle.
Place......	Ashland	Tuscaloosa	Holbrook	Prescott	Augusta	Danville	Bagdad	Mojave	Modesto
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude.	33 16	33 12	34 55	34 34	35 17	35 05	34 35	35 03	37 38
Longitude.	85 51	87 33	110 10	112 30	91 22	93 25	115 53	118 10	120 59
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750.......	3 22 E	....	....	....	....	....	....	....	....
1760.......	3 58	....	....	....	....	....	....	....	....
1770.......	4 34	5 37 E	....	....	....	....	....	....	....
1780.......	5 05	6 08	....	....	....	....	....	10 35E	12 21 E
1790.......	5 32	6 35	....	....	....	....	....	11 09	12 47
1800.......	5 53	6 57	....	....	7 19 E	....	....	11 43	13 16
1810.......	6 07	7 14	....	....	7 41	....	....	12 18	13 45
1820.......	6 13	7 22	....	....	7 54	....	....	12 50	14 14
1830.......	6 10	7 22	....	....	8 01	9 20 E	13 06 E	13 20	14 41
1840.......	5 59	7 15	....	....	7 58	9 20	13 32	13 47	15 06
1850.......	5 41	7 01	13 32 E	13 23 E	7 47	9 12	13 52	14 08	15 29
1860.......	5 16	6 40	13 43	13 37	7 28	8 58	14 07	14 24	15 49
1870.......	4 48	6 13	13 46	13 44	7 04	8 39	14 16	14 35	16 04
1880.......	4 10	5 37	13 39	13 44	6 30	8 09	14 26	14 51	16 08
1890.......	3 29	4 55	13 24	13 36	5 53	7 34	14 24	14 51	16 13
1900.......	3 02	4 30	13 28	13 43	5 28	7 12	14 33	15 05	16 31
1905.......	2 58	4 28	13 42	14 01	5 28	7 12	14 52	15 25	16 51
1910.......	2 56	4 29	14 05	14 25	5 34	7 21	15 17	15 49	17 15
1915.......	2 58	4 33	14 21	14 42	5 42	7 32	15 34	16 06	17 30
1920.......	3 00 E	4 36 E	14 25 E	14 46 E	5 45 E	7 35 E	15 38 E	16 10E	17 32 E
Annual change in 1920...	′ 0.0	′ 0.3 incr.	′ 0.3 incr.	′ 0.3 incr.	′ 0.0	′ 0.1 incr.	′ 0.3 incr.	′ 0.3 incr.	′ 0.0

Secular change of the magnetic declination in the United States—Continued.

Region.	Calif., north.	Colo., east.	Colo., west.	Conn.	Del.	D. C.	Fla., south.	Fla., middle.	Fla., northeast.
Place......	Redding	Hugo	Montrose	Hartford	Dover	Washington	Miami	Bartow	Jacksonville
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude..	40 36	39 08	38 29	41 45	39 09	38 55	25 46	27 53	30 22
Longitude.	122 24	103 29	107 53	72 40	75 31	77 02	80 11	81 51	81 40
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750.......	....	....	....	5 45W	3 23W	1 41W	4 25 E	3 29 E	2 29 E
1760.......	....	....	....	5 16	2 46	1 02	4 55	4 03	3 06
1770.......	....	....	....	4 55	2 16	0 28	5 20	4 33	3 42
1780.......	14 07 E	....	....	4 43	1 52	0 01W	5 40	4 59	4 14
1790.......	14 35	....	....	4 41	1 37	0 19 E	5 51	5 17	4 39
1800.......	15 04	....	....	4 49	1 33	0 28	5 55	5 29	4 57
1810.......	15 34	....	....	5 06	1 37	0 28	5 51	5 31	5 06
1820.......	16 04	....	....	5 32	1 52	0 19 E	5 40	5 25	5 06
1830.......	16 33	....	....	6 05	2 16	0 01W	5 20	5 11	4 57
1840.......	17 01	....	....	6 45	2 46	0 28	4 55	4 49	4 39
1850.......	17 26	13 43 E	14 32 E	7 29	3 23	1 02	4 25	4 22	4 14
1860.......	17 47	13 46	14 40	8 07	4 03	1 41	3 53	3 50	3 42
1870.......	18 06	13 42	14 41	8 41	4 41	2 21	3 18	3 15	3 06
1880.......	18 15	13 27	14 29	9 22	5 20	3 00	2 43	2 37	2 27
1890.......	18 20	12 56	14 05	9 47	5 51	3 36	2 13	2 05	1 52
1900.......	18 40	12 49	14 04	10 21	6 29	4 11	1 44	1 35	1 21
1905.......	19 00	13 00	14 17	10 41	6 48	4 29	1 36	1 28	1 13
1910.......	19 24	13 15	14 35	11 09	7 13	4 51	1 31	1 24	1 07
1915.......	19 37	13 26	14 47	11 38	7 37	5 13	1 31	1 23	1 04
1920.......	19 38 E	13 25 E	14 47 E	11 58W	7 55W	5 29W	1 33 E	1 25 E	1 04 E
Annual change in 1920...	′ 0.3 decr.	′ 0.8 decr.	′ 0.6 decr.	′ 4.0 incr.	′ 3.7 incr.	′ 3.4 incr.	′ 0.5 incr.	′ 0.6 incr.	′ 0.0

Region.	Fla., n. w.	Ga., east.	Ga., west.	Idaho, s. e.	Idaho, s. w.	Idaho, north.	Ill., east.	Ill., west.	Ind.
Place......	Tallahassee	Millen	Americus	Pocatello	Boise	Pierce	Urbana	Rushville	Indianapolis
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude..	30 26	32 48	32 05	42 52	43 37	46 29	40 06	40 08	39 48
Longitude.	84 18	82 00	84 13	112 26	116 12	115 48	88 14	90 34	86 12
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750.......	2 57 E	2 20 E	3 17 E	....	....	....	....	....	....
1760.......	3 34	2 57	3 54	....	....	....	....	....	....
1770.......	4 09	3 32	4 29	....	....	....	....	....	....
1780.......	4 41	4 03	5 01	....	....	....	....	....	....
1790.......	5 07	4 27	5 27	....	....	....	....	....	....
1800.......	5 27	4 43	5 46	....	....	....	6 25 E	7 16 E	4 41E
1810.......	5 39	4 51	5 56	....	....	....	6 45	7 43	4 56
1820.......	5 43	4 49	5 58	....	....	....	6 55	8 03	5 01
1830.......	5 38	4 39	5 52	....	....	....	6 55	8 08	4 56
1840.......	5 25	4 20	5 36	....	....	20 15 E	6 45	8 06	4 41
1850.......	5 05	3 53	5 13	17 41 E	18 10 E	20 40	6 25	7 52	4 18
1860.......	4 38	3 21	4 44	17 57	18 30	21 00	5 57	7 30	3 47
1870.......	4 06	2 44	4 09	18 05	18 45	21 13	5 29	7 05	3 17
1880.......	3 27	2 06	3 30	17 59	18 45	21 10	4 53	6 27	2 42
1890.......	2 50	1 28	2 52	17 48	18 39	21 10	4 12	5 45	2 02
1900.......	2 22	0 56	2 23	17 55	18 51	21 23	3 39	5 14	1 28
1905.......	2 18	0 46	2 16	18 09	19 08	21 38	3 32	5 10	1 19
1910.......	2 17	0 40	2 13	18 29	19 30	21 58	3 26	5 08	1 10
1915.......	2 19	0 35	2 12	18 39	19 41	22 06	3 22	5 08	1 02
1920.......	2 23 E	0 33 E	2 13 E	18 36 E	19 39 E	22 02 E	3 14 E	5 00 E	0 53 E
Annual change in 1920...	0.′7 incr.	0.′6 decr.	0.′0	1.′0 decr.	0.′8 decr.	1.′2 decr.	2.′1 decr.	2.′0 decr.	2.′2 decr.

Secular change of the magnetic declination in the United States—Continued.

Region.	Iowa, east.	Iowa, west.	Kans., east.	Kans., west.	Ky., east.	Ky., middle.	Ky., west.	La.	Me., n. e.
Place......	Walker	Sac City	Emporia	Ness City	Manchester	Hodgenville	Princeton	Winnfield	Eastport
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude..	42 17	42 25	38 25	38 28	37 10	37 34	37 07	31 57	44 55
Longitude.	91 46	95 00	96 12	99 54	83 46	85 43	87 53	92 36	67 00
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750.......	....	....	....	....	....	....	....	....	12 22W
1760.......	....	....	....	....	....	....	....	....	12 10
1770.......	....	....	....	....	....	....	....	....	12 10
1780.......	....	....	....	....	....	....	....	....	12 22
1790.......	....	....	....	....	....	....	....	....	12 43
1800.......	....	....	....	....	3 27 E	5 54 E	6 42 E	8 16 E	13 15
1810.......	....	....	....	....	3 37	6 08	7 00	8 37	13 55
1820.......	8 54 E	10 26 E	....	....	3 38	6 13	7 09	8 53	14 40
1830.......	9 05	10 42	....	....	3 30	6 09	7 09	9 01	15 29
1840.......	9 06	10 49	....	....	3 13	5 56	7 00	9 00	16 19
1850.......	8 56	10 45	11 32 E	12 23 E	2 50	5 36	6 42	8 52	17 15
1860.......	8 37	10 32	11 26	12 22	2 19	5 06	6 14	8 36	18 00
1870.......	8 10	10 10	11 13	12 11	1 42	4 32	5 44	8 12	18 30
1880.......	7 30	9 34	10 48	11 53	1 01	3 50	5 00	7 38	18 50
1890.......	6 45	8 51	10 12	11 20	0 19 E	3 12	4 26	7 07	19 00
1900.......	6 14	8 25	9 54	11 08	0 15W	2 39	3 56	6 46	19 16
1905.......	6 12	8 27	9 57	11 15	0 26	2 30	3 51	6 50	19 31
1910.......	6 13	8 33	10 05	11 27	0 38	2 22	3 47	7 00	20 01
1915.......	6 14	8 39	10 13	11 37	0 48	2 15	3 45	7 12	20 31
1920.......	6 06 E	8 32 E	10 12 E	11 35 E	0 56W	2 09 E	3 41 E	7 19 E	20 47W
Annual change in 1920...	2.′3 decr.	2.′1 decr.	1.′0 decr.	0.′8 decr.	1.′9 incr.	1.′6 decr.	1.′2 decr.	1.′1 incr.	3.′3 incr.

Region.	Me., middle.	Me., s. w.	Md.	Mass., east.	Mass., west.	Mich., north.	Mich., s. e.	Mich., s. w.	Minn., s. e.
Place......	Bangor	Portland	Baltimore	Boston	Pittsfield	Marquette	Lapeer	Grand Haven	St. Paul
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude..	44 48	43 39	39 18	42 20	42 26	46 33	43 03	43 04	44 58
Longitude.	68 48	70 17	76 35	71 01	73 16	87 22	83 20	86 12	93 06
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750.......	10 45W	8 44W	3 05W	7 46W	6 22W	....	....	....	....
1760.......	10 29	8 25	2 26	7 19	5 53	....	....	....	....
1770.......	10 27	8 20	1 52	7 00	5 32	....	....	....	....
1780.......	10 33	8 20	1 25	6 50	5 20	....	....	....	....
1790.......	10 46	8 25	1 05	6 50	5 18	....	....	....	....
1800.......	11 11	8 44	0 56	7 01	5 26	....	....	....	....
1810.......	11 45	9 12	0 56	7 20	5 43	....	....	....	....
1820.......	12 26	9 48	1 05	7 47	6 09	6 45 E	2 35 E	5 07 E	11 20 E
1830.......	13 10	10 28	1 25	8 22	6 42	6 45	2 26	5 04	11 33
1840.......	13 55	11 07	1 52	9 04	7 22	6 31	2 06	4 48	11 37
1850.......	14 43	11 48	2 26	9 48	8 06	6 05	1 38	4 24	11 27
1860.......	15 26	12 28	3 05	10 28	8 44	5 28	1 02	3 52	11 09
1870.......	15 56	12 58	3 45	11 01	9 18	4 41	0 18 E	3 12	10 41
1880.......	16 23	13 32	4 24	11 30	9 59	3 50	0 29W	2 25	10 04
1890.......	16 42	14 00	5 00	11 58	10 26	3 03	1 13	1 39	9 17
1900.......	17 03	14 29	5 35	12 33	10 59	2 26	1 46	1 03	8 45
1905.......	17 19	14 46	5 53	12 52	11 17	2 13	2 00	0 51	8 45
1910.......	17 49	15 16	6 15	13 22	11 46	2 03	2 15	0 40	8 46
1915.......	18 19	15 46	6 38	13 52	12 15	1 53	2 30	0 29	8 42
1920.......	18 37W	16 05W	6 55W	14 12W	12 35W	1 35 E	2 46W	0 15 E	8 31 E
Annual change in 1920...	3.′6 incr.	3.′9 incr.	3.′5 incr.	4.′0 incr.	4.′0 incr.	3.′9 decr.	3.′5 incr.	3.′1 decr.	2.′7 decr.

Secular change of the magnetic declination in the United States—Continued.

Region.	Minn., s. w.	Minn., n. e.	Minn., n. w.	Miss., east.	Miss., west.	Mo., east.	Mo., west.	Mont., east.	Mont., middle.
Place	Marshall	Hibbing	Bagley	Meridian	Vicksburg	Hermann	Sedalia	Miles City	Lewistown
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude	44 24	47 27	47 32	32 23	32 21	38 42	38 43	46 24	47 04
Longitude	95 51	92 56	95 23	88 44	90 53	91 26	93 14	105 53	109 26
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	....	....	....	....	....	....	....	....	....
1760	....	....	....	....	....	....	....	....	....
1770	....	....	....	....	....	....	....	....	....
1780	....	....	....	....	....	....	....	....	....
1790	....	....	....	....	....	....	....	....	....
1800	....	....	....	7 03 E	7 50 E	....	....	....	....
1810	....	....	....	7 22	8 11	....	....	....	....
1820	....	10 31 E	....	7 32	8 23	9 09 E	9 51 E	....	....
1830	....	10 44	13 01 E	7 35	8 28	9 16	9 57	....	....
1840	11 44 E	10 46	13 08	7 30	8 25	9 15	9 57	....	19 29 E
1850	11 39	10 37	13 04	7 18	8 15	9 03	9 51	17 38 E	19 50
1860	11 26	10 16	12 48	7 00	7 59	8 43	9 36	17 46	20 04
1870	11 03	9 41	12 20	6 36	7 35	8 19	9 16	17 42	20 08
1880	10 32	8 59	11 43	6 02	7 04	7 40	8 41	17 25	19 56
1890	9 48	8 14	10 58	5 19	6 22	7 01	8 01	16 56	19 35
1900	9 17	7 41	10 27	4 55	6 00	6 33	7 37	16 52	19 38
1905	9 19	7 39	10 30	4 53	6 02	6 30	7 39	17 04	19 51
1910	9 25	7 41	10 36	4 57	6 08	6 31	7 45	17 18	20 07
1915	9 30	7 37	10 38	5 03	6 16	6 34	7 51	17 23	20 13
1920	9 20 E	7 22 E	10 25 E	5 08 E	6 22 E	6 29 E	7 47 E	17 16 E	20 07 E
Annual change in 1920	2′.5 decr.	3′.4 decr.	3′.1 decr.	0′.8 incr.	0′.8 incr.	1′.4 decr.	1′.2 decr.	2′.0 decr.	1′.8 decr.

Region.	Mont., west.	Nebr., east.	Nebr., middle.	Nebr., west.	Nev., east.	Nev., west.	N. H.	N. J.	N. Mex., east.
Place	Ovando	Albion	Thedford	Alliance	Elko	Hawthorne	Plymouth	Trenton	Santa Rosa
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude	47 02	41 41	41 59	42 06	40 51	38 32	43 46	40 15	34 56
Longitude	113 08	97 59	100 31	102 51	115 46	118 38	71 42	74 48	104 41
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	....	....	....	....	....	....	8 41 W	4 47 W	....
1760	....	....	....	....	....	....	8 07	4 08	....
1770	....	....	....	....	....	....	7 42	3 35	....
1780	....	....	....	....	....	....	7 26	3 10	....
1790	....	....	....	....	....	....	7 21	2 54	....
1800	....	....	....	....	....	....	7 28	2 49	....
1810	....	....	....	....	....	....	7 45	2 54	....
1820	....	12 26 E	....	....	....	....	8 11	3 10	....
1830	....	12 44	....	....	....	....	8 50	3 35	....
1840	20 21 E	12 54	....	....	....	....	9 35	4 08	....
1850	20 46	12 54	13 45 E	15 26 E	17 18 E	16 15 E	10 25	4 47	12 43 E
1860	21 05	12 46	13 41	15 26	17 34	16 36	11 10	5 26	12 47
1870	21 15	12 29	13 28	15 17	17 44	16 51	11 47	6 05	12 43
1880	21 06	11 59	12 59	14 49	17 46	16 58	12 17	6 45	12 25
1890	20 56	11 22	12 25	14 19	17 38	17 00	12 40	7 15	12 00
1900	21 06	11 01	12 10	14 09	17 48	17 14	13 11	7 50	11 57
1905	21 20	11 06	12 17	14 17	18 04	17 32	13 29	8 10	12 10
1910	21 38	11 14	12 27	14 30	18 27	17 56	13 59	8 35	12 28
1915	21 45	11 20	12 34	14 38	18 40	18 09	14 29	9 00	12 43
1920	21 40 E	11 15 E	12 29 E	14 34 E	18 40 E	18 10 E	14 49 W	9 19 W	12 47 E
Annual change in 1920	1′.5 decr.	1′.7 decr.	1′.6 decr.	1′.5 decr.	0′.5 decr.	0′.2 decr.	4′.0 incr.	4′.0 incr.	0′.3 incr.

Secular change of the magnetic declination in the United States—Continued.

Region.	N. Mex., west.	N. Y., east.	N. Y., middle.	N. Y., west.	N. C., east.	N. C., middle.	N. C., west.	N. Dak., east.	N. Dak., middle.
Place......	Laguna	Albany	Syracuse	Buffalo	New Bern	Troy	Asheville	Jamestown	Bismarck
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude ..	35 03	42 40	43 02	42 54	35 07	35 22	35 35	46 53	46 48
Longitude.	107 24	73 45	76 10	78 54	77 03	79 54	82 32	98 42	100 47
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750.......	....	7 36 W	5 32 W	....	0 18 W	0 36 E	....	....	....
1760.......	....	6 54	4 49	....	0 18 E	1 12	....	....	....
1770.......	....	6 18	4 10	....	0 50	1 46	....	....	....
1780.......	....	5 51	3 38	1 49 W	1 17	2 15	....	....	....
1790.......	....	5 35	3 16	1 21	1 35	2 36	....	....	....
1800.......	....	5 29	3 05	1 05	1 44	2 48	4 06 E	....	....
1810.......	....	5 35	3 05	0 58	1 44	2 51	4 12	....	....
1820.......	....	5 51	3 16	1 05	1 35	2 45	4 09	....	....
1830.......	....	6 18	3 38	1 21	1 16	2 29	3 57	14 14 E	....
1840.......	....	6 54	4 10	1 49	0 50	2 05	3 35	14 24	....
1850.......	13 26 E	7 40	4 49	2 23	0 17 E	1 34	3 07	14 24	16 31 E
1860.......	13 33	8 26	5 38	3 07	0 19 W	1 00	2 35	14 14	16 26
1870.......	13 34	9 05	6 15	3 46	1 00	0 22 E	1 57	13 56	16 12
1880.......	13 22	9 52	7 08	4 37	1 40	0 18 W	1 17	13 27	15 46
1890.......	13 02	10 13	7 49	5 19	2 16	0 55	0 41	12 44	15 06
1900.......	13 02	10 49	8 26	5 57	2 52	1 29	0 09 E	12 19	14 47
1905.......	13 16	11 07	8 44	6 14	3 08	1 42	0 02 W	12 24	14 54
1910.......	13 36	11 35	9 09	6 36	3 25	1 57	0 15	12 33	15 04
1915.......	13 52	12 03	9 34	6 58	3 42	2 12	0 27	12 34	15 05
1920.......	13 56 E	12 23 W	9 54 W	7 16 W	3 54 W	2 22 W	0 34 W	12 23 E	14 55 E
Annual change in 1920......	0′.3 incr.	4′.0 incr.	4′.0 incr.	4′.0 incr.	2′.5 incr.	2′.0 incr.	1′.5 incr.	2′.8 decr.	2′.6 decr.

Region.	N. Dak., west.	Ohio, east.	Ohio, west.	Okla., east.	Okla., west.	Ore., east.	Ore., west.	Pa., east.	Pa., middle.
Place......	Dickinson	Canton	Urbana	Okmulgee	Watonga	Sumpter	Detroit	Wilkes-Barre	Lockhaven
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude...	46 53	40 49	40 06	35 38	35 51	44 45	44 43	41 13	41 09
Longitude.	102 46	81 24	83 44	95 56	98 24	118 13	122 08	75 54	77 26
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750.......	....	....	....	....	....	....	....	4 43 W	....
1760.......	....	....	....	....	....	....	....	3 59	....
1770.......	....	....	....	....	....	....	....	3 19	....
1780.......	....	....	....	....	....	....	....	2 46	2 03 W
1790.......	....	....	....	....	....	....	....	2 26	1 40
1800.......	....	2 07 E	4 11 E	....	....	....	16 30 E	2 17	1 26
1810.......	....	2 16	4 23	....	....	....	17 05	2 18	1 23
1820.......	....	2 14	4 24	....	....	....	17 40	2 31	1 32
1830.......	....	2 02	4 16	....	....	....	18 15	2 53	1 52
1840.......	....	1 41	3 58	....	....	....	18 50	3 24	2 22
1850.......	17 43 E	1 12	3 32	10 20 E	11 14 E	19 15 E	19 20	4 02	2 59
1860.......	17 43	0 36 E	2 59	10 10	11 11	19 40	19 45	4 42	3 39
1870.......	17 33	0 00	2 25	9 55	10 59	19 58	20 05	5 21	4 19
1880.......	17 10	0 41 W	1 47	9 30	10 36	20 09	20 17	6 02	4 59
1890.......	16 33	1 20	1 08	9 00	10 09	20 11	20 27	6 36	5 39
1900.......	16 21	1 57	0 31	8 40	9 55	20 26	20 50	7 13	6 17
1905.......	16 30	2 13	0 18	8 43	10 02	20 44	21 09	7 33	6 36
1910.......	16 42	2 30	0 05 E	8 53	10 15	21 07	21 33	7 58	6 59
1915.......	16 44	2 47	0 08 W	9 03	10 27	21 19	21 47	8 22	7 22
1920.......	16 35 E	3 01 W	0 20 W	9 06 E	10 30 E	21 17 E	21 47E	8 41 W	7 40 W
Annual change in 1920...	2′.4 decr.	3′.0 incr.	2′.6 incr.	0′.1 incr.	0′.1 incr.	0′.8 decr.	0′.7 decr.	4′.0 incr.	3′.9 incr.

Secular change of the magnetic declination in the United States—Continued.

Region.	Pa., west.	R. I.	S. C., east.	S. C., west.	S. Dak., east.	S. Dak., middle.	S. Dak., west.	Tenn., east.	Tenn., middle.
Place	Indiana	Newport	Marion	Aiken	Huron	Murdo	Rapid City	Knoxville	Woodbury
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude	40 39	41 30	34 11	33 34	44 21	43 54	44 05	35 56	35 49
Longitude	79 12	71 20	79 24	81 44	98 10	100 43	103 12	83 57	86 02
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	....	7 04 W	1 09 E	2 19 E	....	....	....	....	....
1760	....	6 37	1 46	2 56	....	....	....	....	....
1770	....	6 18	2 19	3 31	....	....	....	....	....
1780	0 07 W	6 08	2 47	4 01	....	....	....	....	....
1790	0 17 E	6 08	3 08	4 24	....	....	....	....	....
1800	0 32	6 19	3 19	4 39	....	....	....	3 48 E	6 00 E
1810	0 38	6 38	3 24	4 45	....	....	....	3 57	6 13
1820	0 32	7 05	3 16	4 42	....	....	....	3 56	6 17
1830	0 16 E	7 40	3 02	4 30	....	....	....	3 46	6 13
1840	0 09 W	8 22	2 39	4 09	13 08 E	....	....	3 27	6 01
1850	0 42	9 06	2 08	3 42	13 08	15 00 E	16 20 E	3 02	5 41
1860	1 20	9 46	1 34	3 08	12 59	14 55	16 20	2 29	5 15
1870	1 59	10 19	0 55	2 31	12 42	14 42	16 10	1 53	4 42
1880	2 39	10 50	0 17 E	1 53	12 16	14 19	15 50	1 13	4 05
1890	3 18	11 17	0 22 W	1 16	11 36	13 42	15 17	0 38	3 29
1900	3 55	11 52	0 58	0 42	11 12	13 24	15 07	0 05 E	2 58
1905	4 13	12 11	1 12	0 32	11 17	13 31	15 15	0 05 W	2 51
1910	4 33	12 40	1 24	0 22	11 25	13 41	15 27	0 15	2 46
1915	4 53	13 10	1 36	0 14	11 29	13 46	15 33	0 23	2 43
1920	5 10 W	13 30 W	1 44 W	0 09 E	11 21 E	13 39 E	15 27 E	0 28 W	2 40 E
Annual change in 1920	3.′6 incr.	4.′0 incr.	1.′7 incr.	1.′1 decr.	2.′3 decr.	2.′1 decr.	1.′9 decr.	1.′4 incr.	1.′0 decr.

Region.	Tenn., west.	Tex., east.	Tex., middle.	Tex., west.	Tex., n. w.	Utah.	Vt.	Va., east.	Va., middle.
Place	Huntingdon	Houston	Johnson City	Pecos	Floydada	Manti	Rutland	Richmond	Lynchburg
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude	36 00	29 47	30 17	31 26	33 59	39 16	43 37	37 33	37 24
Longitude	88 23	95 21	98 28	103 33	101 15	111 40	72 58	77 28	79 08
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	....	....	....	....	....	....	7 32 W	1 18 W	....
1760	....	....	....	....	....	....	6 58	0 42	0 06 W
1770	....	....	....	....	....	....	6 33	0 10 W	0 28 E
1780	....	....	....	....	....	....	6 17	0 15 E	0 57
1790	....	....	....	....	....	....	6 12	0 33	1 19
1800	7 01 E	....	....	....	....	....	6 19	0 42	1 32
1810	7 18	....	....	....	....	....	6 36	0 42	1 37
1820	7 26	8 59 E	....	....	....	....	7 02	0 33	1 32
1830	7 26	9 14	9 40 E	10 43 E	....	....	7 37	0 15 E	1 19
1840	7 18	9 23	9 51	10 57	....	....	8 18	0 10 W	0 57
1850	7 01	9 23	9 56	11 05	11 15 E	16 27 E	9 02	0 41	0 31 E
1860	6 37	9 16	9 51	11 04	11 17	16 40	9 48	1 17	0 04 W
1870	6 07	8 54	9 39	10 57	11 10	16 45	10 28	1 56	0 43
1880	5 31	8 23	9 19	10 45	10 55	16 40	11 08	2 34	1 23
1890	4 55	7 52	8 49	10 21	10 24	16 25	11 31	3 11	2 00
1900	4 26	7 41	8 41	10 15	10 16	16 30	12 04	3 46	2 34
1905	4 22	7 50	8 53	10 27	10 27	16 44	12 22	4 03	2 50
1910	4 20	8 03	9 09	10 45	10 43	17 05	12 52	4 23	3 07
1915	4 22	8 18	9 25	11 03	10 58	17 19	13 22	4 43	3 24
1920	4 21 E	8 27 E	9 34 E	11 10 E	11 02 E	17 19 E	13 42 W	4 57 W	3 36 W
Annual change in 1920	0.′8 decr.	1.′5 incr.	1.′5 incr.	1.′0 incr.	0.′5 incr.	0.′5 decr.	4.′0 incr.	3.′0 incr.	2.′6 incr.

Secular change of the magnetic declination in the United States—Continued.

Region.	Va., west.	Wash., east.	Wash., west.	W. Va.	Wis., east.	Wis., west.	Wyo., east.	Wyo., west.
Place	Wytheville	Wilson Creek	Seattle	Sutton	Shawamo	Stanley	Douglas	Lander
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Latitude	36 57	47 26	47 33	38 39	44 47	44 57	42 44	42 50
Longitude	81 04	119 00	122 15	80 43	88 37	90 56	105 22	108 40
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750								
1760								
1770								
1780			17 05 E					
1790			17 38	1 29 E				
1800	2 48 E		18 13	1 44				
1810	2 55		18 50	1 51				
1820	2 52		19 27	1 48	7 24 E	8 49 E		
1830	2 43		20 02	1 36	7 27	8 58		
1840	2 24		20 35	1 15	7 18	8 55		
1850	1 59	21 15 E	21 05	0 47	6 58	8 41	15 55 E	16 53 E
1860	1 26	21 36	21 30	0 12 E	6 29	8 17	16 00	17 05
1870	0 48	21 51	21 51	0 26 W	5 52	7 45	16 00	17 09
1880	0 08 E	21 55	22 04	1 07	5 03	7 01	15 45	16 57
1890	0 32 W	22 05	22 17	1 45	4 19	6 15	15 20	16 37
1900	1 05	22 21	22 41	2 21	3 44	5 42	15 15	16 41
1905	1 18	22 37	23 02	2 37	3 34	5 37	15 26	16 53
1910	1 32	22 59	23 32	2 54	3 27	5 34	15 42	17 13
1915	1 45	23 07	23 47	3 11	3 20	5 31	15 54	17 25
1920	1 55 W	23 03 E	23 46 E	3 23 W	3 06 E	5 19 E	15 50 E	17 21 E
	′	′	′	′	′	′	′	′
Annual change in 1920	2.2 incr.	1.1 decr.	0.9 decr.	2.7 incr.	3.1 decr.	2.9 decr.	1.4 decr.	1.2 decr

DIURNAL VARIATION.

The magnetic declination undergoes a systematic change in the course of the day. During the night it ordinarily differs very little from the average value for the day, but in the early morning an easterly motion sets in, the extreme easterly position being reached about 8 or 9 a. m. This is followed by a westerly motion, the extreme westerly position being reached about 1 or 2 p. m. By 6 p. m. it is back again to the average. The magnitude of this variation is indicated by the following table, which gives the average diurnal variation for a series of years at three of the magnetic observatories of this bureau. For individual days of ordinary character, the departures from the daily mean may be 50 per cent greater than the values given in the table and at the time of a magnetic storm the daily range not infrequently amounts to half a degree or more.

While the diurnal variation can ordinarily be neglected for the class of work done with a compass, yet, where as great accuracy as possible is sought, it should be taken into account. The difference in declination between morning and afternoon may easily amount to 10 minutes and an angle of 10 minutes subtends an arc of 15 feet at a distance of a mile. The surveyor should also be on the lookout for magnetic storms, which may be indicated by an unsteady needle.

Diurnal variation of declination at magnetic observatories.

[**A plus sign indicates that east declination is greater or west declination is less than the mean for the day.**]

Hour.	January, February, November, December.			March, April, September, October.			May, June, July, August.		
	Sitka.	Chelten-ham.	Tucson.	Sitka.	Chelten-ham.	Tucson.	Sitka.	Chelten-ham.	Tucson.
	′	′	′	′	′	′	′	′	′
1 a. m.	−0.2	−0.2	−0.2	−0.2	+0.1	0.0	−0.9	+0.1	0.0
2 a. m.	−0.1	−0.3	−0.2	−0.2	+0.3	+0.1	−0.7	+0.2	+0.1
3 a. m.	+0.1	−0.1	−0.2	+0.1	+0.5	+0.2	−0.4	+0.3	+0.2
4 a. m.	+0.2	+0.1	−0.1	+0.4	+0.8	+0.3	+0.9	+0.8	+0.5
5 a. m.	+0.4	+0.3	0.0	+1.0	+1.1	+0.5	+2.6	+1.7	+1.0
6 a. m.	+0.6	+0.6	+0.2	+2.1	+2.0	+1.2	+4.5	+3.5	+2.1
7 a. m.	+1.1	+1.1	+0.6	+3.4	+3.4	+2.5	+6.1	+4.9	+3.5
8 a. m.	+1.7	+2.0	+1.3	+4.6	+4.2	+3.2	+7.1	+5.3	+4.0
9 a. m.	+1.9	+2.6	+1.7	+4.6	+3.7	+2.5	+6.7	+4.0	+2.8
10 a. m.	+1.5	+2.0	+1.4	+3.4	+1.8	+0.8	+4.7	+1.1	+0.5
11 a. m.	+0.6	+0.2	+0.2	+1.5	−0.9	−1.0	+1.2	−1.9	−1.6
Noon	−0.2	−1.7	−1.1	−0.6	−3.2	−2.3	−1.8	−4.1	−2.8
1 p. m.	−1.0	−2.7	−1.7	−2.2	−4.3	−2.7	−3.6	−5.0	−3.2
2 p. m.	−1.5	−2.6	−1.6	−3.0	−4.2	−2.3	−4.8	−4.7	−2.8
3 p. m.	−1.6	−2.0	−1.1	−3.2	−3.1	−1.5	−5.3	−3.5	−2.0
4 p. m.	−1.4	−1.2	−0.5	−3.0	−1.8	−0.8	−4.8	−2.2	−1.1
5 p. m.	−1.1	−0.5	0.0	−2.5	−0.8	−0.4	−3.7	−0.8	−0.4
6 p. m.	−0.6	0.0	+0.2	−1.9	−0.4	−0.2	−2.3	0.0	−0.1
7 p. m.	−0.2	+0.3	+0.4	−1.3	−0.1	−0.1	−1.2	0.0	−0.3
8 p. m.	0.0	+0.5	+0.4	−0.9	0.0	0.0	−0.8	−0.1	−0.2
9 p. m.	−0.1	+0.6	+0.4	−0.6	+0.2	0.0	−0.8	0.0	−0.2
10 p. m.	−0.1	+0.5	+0.2	−0.7	+0.2	0.0	−0.9	+0.1	−0.1
11 p. m.	−0.1	+0.4	0.0	−0.5	+0.2	0.0	−0.8	+0.1	−0.1
Midnight	0.0	+0.1	−0.1	−0.4	+0.2	0.0	−0.9	+0.1	0.0

DETERMINATION OF THE TRUE MERIDIAN.

Because of the irregular distribution of the earth's magnetism, only an approximate value of the magnetic declination can be given for a place at which it has not been determined by observation. When a more accurate value is needed the true meridian must be determined, as the declination is the angle between the true meridian and the magnetic meridian. This may be done by observations of the sun or Polaris. Five methods will be explained, three involving the use of a surveyor's transit and two requiring no instrumental equipment.

With care the methods involving the use of a surveyor's transit should give the true meridian within 1 minute of arc, the other methods within 2 or 3 minutes, an accuracy ample for ordinary compass surveys.

(*a*) *With a plumb line and peep sight.*—I. By observations of Polaris at elongation; II. By noting when Polaris and another star are in the same vertical plane.

(*b*) *With a surveyor's transit.*—III. By observations of Polaris at elongation; IV. By observations of Polaris at any hour; V. By observations of the sun.

As a result of the rotation of the earth about its axis, Polaris, like other stars, appears to move in a circle about the pole of the heavens. It is said to be at culmination when it is in the vertical plane defined by the observer and the pole (upper culmination when it is above the pole) and at elongation when it reaches its extreme easterly and westerly positions with respect to the pole. At culmination its apparent motion is nearly horizontal, from east to west at upper culmination and from west to east at lower culmination. At elongation its apparent motion is nearly vertical, upward at eastern elongation and downward at western elongation.

The azimuth of Polaris is the angle at the observing station between the vertical plane through the pole and the one through the star. For a short time before and after elongation there is practically no change in the azimuth of Polaris and that time is usually selected for observing it for the purpose of determining the true meridian.

I. OBSERVATIONS OF POLARIS AT ELONGATION.

Attach the plumb line to a support situated as far above the ground as practicable, such as the limb of a tree or a piece of board fastened to a telegraph pole or a building, affording a clear view in a north and south direction.

The plumb bob may consist of any heavy material, a brick or a piece of iron or stone weighing 4 or 5 pounds serving to keep the plumb line straight and vertical as well as one of turned and finished metal.

Strongly illuminate the plumb line just below its support by a flash light or lantern, care being taken to obscure the source of light from the view of the observer.

For a peep sight nail two strips of tin or thin board with straight edges to a squared block of wood so that they will stand vertical about one-sixteenth of an inch apart when the block rests on a horizontal surface.

Provide a rest for the peep sight at a convenient height above the ground, at such a distance south of the plumb line that when viewed through the peep sight Polaris will appear about a foot below the support of the plumb line. The top of this rest must be level and large enough to allow for sliding the peep sight east or west. The position of the rest should be fixed by trial the night preceding that set for observations, and it should be firmly secured in the proper position.

About 30 minutes before the time of elongation, as given in Table I, bring the peep sight into the same line of sight with the plumb line and Polaris.

The star will move off the plumb line to the east as it approaches eastern elongation; to the west for western elongation. Move the peep sight to the west or east, as the case may be, keeping it in line with the star and the plumb line, until the star appears stationary, thus indicating that it has reached elongation. The peep sight will then be secured in place by a clamp or weight and further operations will be deferred until daylight.

By daylight place a slender rod at a distance of 200 or 300 feet from the peep sight and exactly in range with it and the plumb line; carefully measure this distance.

Find from Table II the azimuth of Polaris for the year of observation and the latitude of the place.

Find from Table III the natural tangent of this angle and multiply it by the distance from the peep sight to the rod. The product will be the distance to be laid off from the rod, to the west in the case of eastern elongation, or to the east for western elongation, to a point which with the peep sight will define the direction of the true meridian with a fair degree of accuracy. Set a stub at this point and another exactly below the peep sight, if the meridian is needed for future use.

TABLE I.—*Local mean (astronomical) time of the culminations and elongations of Polaris in the year 1922.*

[Computed for latitude 40° north and longitude 90° or 6^h west of Greenwich.]

Date, 1922.	East elongation.	Upper culmination.	West elongation.	Lower culmination.
	h. m.	*h. m.*	*h. m.*	*h. m.*
Jan. 1	0 54.7	6 50.0	12 45.3	18 48.0
Jan. 15	23 55.4	5 54.7	11 50.0	17 52.7
Feb. 1	22 48.3	4 47.5	10 42.8	16 45.5
Feb. 15	21 53.0	3 52.2	9 47.5	15 50.3
Mar. 1	20 57.8	2 57.0	8 52.3	14 55.0
Mar. 15	20 02.6	2 01.8	7 57.1	13 59.8
Apr. 1	18 55.7	0 54.9	6 50.2	12 52.9
Apr. 15	18 00.6	23 55.9	5 55.1	11 57.8
May 1	16 57.7	22 53.0	4 52.2	10 55.0
May 15	16 02.9	21 58.2	3 57.4	10 00.1
June 1	14 56.2	20 51.5	2 50.7	8 53.5
June 15	14 01.4	19 56.7	1 55.9	7 58.6
July 1	12 58.8	18 54.1	0 53.3	6 56.0
July 15	12 04.0	17 59.3	23 54.6	6 01.3
Aug. 1	10 57.5	16 52.8	22 48.1	4 54.7
Aug. 15	10 02.7	15 58.0	21 53.3	3 59.9
Sept. 1	8 56.1	14 51.4	20 46.7	2 53.3
Sept. 15	8 01.2	13 56.5	19 51.8	1 58.5
Oct. 1	6 58.4	12 53.7	18 49.0	0 55.7
Oct. 15	6 03.4	11 58.7	17 54.0	{ 0 00.7 23 56.8
Nov. 1	4 56.6	10 51.9	16 47.2	22 49.9
Nov. 15	4 01.5	9 56.8	15 52.1	21 54.8
Dec. 1	2 58.5	8 53.8	14 49.1	20 51.8
Dec. 15	2 03.2	7 58.5	13 53.8	19 56.6

(*a*) *To refer the above tabular quantities to years other than 1922:*

For year 1923 add..........1.4
1924 {add........2.8 up to March 1; subtract....1.1 on and after March 1}
1925 add..........0.2
1926 add..........1.5
1927 add..........2.7
1928 {add........4.1 up to March 1; add........0.2 on and after March 1}
1929 add..........1.6
1930 add..........3.1
1931 add..........4.5
1932 {add..........5.9 up to March 1; add..........2.0 on and after March 1}

(*b*) *To refer to any calendar day other than the first and fifteenth of each month* SUBTRACT *the quantities below from the tabular quantity for the* PRECEDING DATE:

Day of month.		Minutes.	Days elapsed.
2 or	16	3.9	1
3	17	7.8	2
4	18	11.8	3
5	19	15.7	4
6	20	19.6	5
7	21	23.5	6
8	22	27.4	7
9	23	31.4	8
10	24	35.3	9
11	25	39.2	10
12	26	43.1	11
13	27	47.0	12
14	28	51.0	13
	29	54.9	14
	30	58.8	15
	31	62.7	16

(*c*) *To refer the table to standard time and to the civil or common method of reckoning:* ADD to the tabular quantities four minutes for every degree of longitude the place is west of the standard meridian and SUBTRACT when the place is east of the standard meridian. The astronomical day begins 12 hours after the civil day, that is, begins at noon on the civil day of the same date, and is reckoned from 0 to 24 hours. Consequently an astronomical time less than 12 hours refers to the same civil day, whereas an astronomical time greater than 12 hours refers to the morning of the next civil day. It will be noticed that for the tabular year two eastern elongations occur on January 14 and two western elongations on July 14. There are also two upper culminations on April 14 and two lower culminations on October 15. The lower culmination either follows or precedes the upper culmintaion by $11^h\ 58^m .0$.

(*d*) *To refer to any other than the tabular latitude between the limits of 10 and 50° north:* ADD to the time of west elongation $0^m .10$ for every degree *south* of 40° and SUBTRACT from the time of west elongation $0^m .16$ for every degree *north* of 40°. Reverse these operations for correcting times of east elongation.

(*e*) *To refer to any other than the tabular longitude:* ADD $0^m. 16$ for each 15° east of the ninetieth meridian and SUBTRACT $0^m .16$ for each 15° west of the ninetieth meridian.

TABLE II.—*Azimuth of Polaris at elongation for any year between 1922 and 1932.*

Latitude.	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
10..........	1 07.8	1 07.4	1 07.2	1 06.8	1 06.5	1 06.2	1 05.9	1 05.6	1 05.3	1 05.0	1 04.7
11..........	08.0	07.7	07.4	07.0	06.7	06.4	06.1	05.8	05.5	05.2	04.9
12..........	08.2	07.9	07.6	07.3	07.0	06.7	06.4	06.0	05.7	05.4	05.1
13..........	08.5	08.2	07.8	07.6	07.2	06.9	06.6	06.3	06.0	05.7	05.3
14..........	08.8	08.5	08.2	07.8	07.5	07.2	06.9	06.6	06.3	05.9	05.6
15..........	09.1	08.8	08.5	08.1	07.8	07.5	07.2	06.9	06.6	06.2	05.9
16..........	09.4	09.1	08.8	08.5	08.2	07.8	07.5	07.2	06.9	06.6	06.2
17..........	09.8	09.5	09.2	08.8	08.5	08.2	07.9	07.5	07.2	06.9	06.6
18..........	10.2	09.8	09.5	09.2	08.9	08.6	08.2	07.9	07.6	07.3	07.0
19..........	10.6	10.2	09.9	09.6	09.3	09.0	08.6	08.3	08.0	07.7	07.3
20..........	11.0	10.7	10.4	10.0	09.7	09.4	09.1	08.7	08.4	08.1	07.8
21..........	11.5	11.2	10.8	10.5	10.2	09.8	09.5	09.2	08.8	08.5	08.2
22..........	12.0	11.6	11.3	11.0	10.6	10.3	10.0	09.7	09.3	09.0	08.7
23..........	12.5	12.2	11.8	11.5	11.2	10.8	10.5	10.2	09.8	09.5	09.2
24..........	13.0	12.7	12.4	12.0	11.7	11.4	11.0	10.7	10.4	10.0	09.7
25..........	13.6	13.3	13.0	12.6	12.3	11.9	11.6	11.3	10.9	10.6	10.3
26..........	14.2	13.9	13.6	13.2	12.9	12.5	12.2	11.9	11.5	11.2	10.9
27..........	14.9	14.6	14.2	13.9	13.5	13.2	12.8	12.5	12.2	11.8	11.5
28..........	15.6	15.2	14.9	14.6	14.2	13.8	13.5	13.2	12.8	12.5	12.1
29..........	16.3	16.0	15.6	15.2	14.9	14.6	14.2	13.9	13.5	13.2	12.8
30..........	17.0	16.7	16.4	16.0	15.6	15.3	14.9	14.6	14.2	13.9	13.5
31..........	17.9	17.5	17.2	16.8	16.4	16.1	15.7	15.4	15.0	14.6	14.3
32..........	18.7	18.3	18.0	17.6	17.2	16.9	16.5	16.2	15.8	15.4	15.1
33..........	19.6	19.2	18.8	18.5	18.1	17.8	17.4	17.0	16.7	16.3	15.9
34..........	20.5	20.1	19.8	19.4	19.0	18.6	18.3	17.9	17.5	17.2	16.8
35..........	21.5	21.1	20.7	20.4	20.0	19.6	19.2	18.9	18.5	18.1	17.7
36..........	22.5	22.1	21.7	21.4	21.0	20.6	20.2	19.8	19.5	19.1	18.7
37..........	23.6	23.2	22.8	22.4	22.0	21.6	21.3	20.9	20.5	20.1	19.7
38..........	24.7	24.3	23.9	23.5	23.2	22.8	22.4	22.0	21.6	21.2	20.8
39..........	25.8	25.5	25.1	24.7	24.3	23.9	23.5	23.1	22.7	22.3	21.9
40..........	27.1	26.7	26.3	25.9	25.5	25.1	24.7	24.3	23.9	23.5	23.1
41..........	28.4	28.0	27.6	27.2	26.8	26.4	26.0	25.6	25.2	24.8	24.4
42..........	29.8	29.4	29.0	28.6	28.2	27.8	27.3	26.9	26.5	26.1	25.7
43..........	31.2	30.8	30.4	30.0	29.6	29.1	28.7	28.3	27.9	27.5	27.1
44..........	32.8	32.4	31.9	31.5	31.1	30.6	30.2	29.8	29.4	29.0	28.5
45..........	34.4	34.0	33.5	33.1	32.6	32.2	31.8	31.4	30.9	30.5	30.1
46..........	36.1	35.6	35.2	34.8	34.3	33.9	33.4	33.0	32.5	32.1	31.7
47..........	37.9	37.4	37.0	36.5	36.1	35.6	35.2	34.7	34.3	33.8	33.4
48..........	39.8	39.3	38.8	38.4	37.9	37.4	37.0	36.5	36.1	35.6	35.2
49..........	41.7	41.3	40.8	40.3	39.9	39.4	38.9	38.5	38.0	37.5	37.1
50..........	1 43.8	1 43.4	1 42.9	1 42.4	1 41.9	1 41.4	1 41.0	1 40.5	1 40.0	1 39.5	1 39.1

Table II was computed with the mean declination of Polaris for the beginning of each year. A more accurate result will be had by applying to the tabular values the following corrections, which depend on the difference between the mean and apparent place of the star and on the latitude.

Middle of—	Correction.				
	Latitude 10°.	Latitude 20°.	Latitude 30°.	Latitude 40°.	Latitude 50°.
	′	′	′	′	′
January	−0.3	−0.4	−0.4	−0.4	−0.5
February	− .3	− .3	− .4	− .4	− .5
March	− .2	− .2	− .2	− .3	− .3
April	− .1	− .1	− .1	− .1	− .1
May	+ .1	+ .1	+ .1	+ .1	+ .1
June	+ .2	+ .2	+ .2	+ .2	+ .2
July	+ .2	+ .2	+ .2	+ .2	+ .3
August	+ .1	+ .1	+ .1	+ .1	+ .1
September	− .1	− .1	− .1	− .1	− .1
October	− .3	− .3	− .3	− .3	− .4
November	− .5	− .5	− .5	− .6	− .7
December	− .6	− .6	− .7	− .8	− .9

TABLE III.—*Natural tangent of angles from 1° 00′ to 1° 50′.*

Angle.	Tangent.	Angle.	Tangent.	Angle.	Tangent.	Angle.	Tangent.	Angle.	Tangent.
° ′		° ′		° ′		° ′		° ′	
1 00	0.01746	1 10	0.02036	1 20	0.02328	1 30	0.02619	1 40	0.02910
01	01775	11	.02066	21	.02357	31	.02648	41	.02939
02	.01804	12	.02095	22	.02386	32	.02677	42	.02968
03	.01833	13	.02124	23	.02415	33	.02706	43	.02997
04	.01862	14	.02153	24	.02444	34	.02735	44	.03026
05	.01891	15	.02182	25	.02473	35	.02764	45	.03055
06	.01920	16	.02211	26	.02502	36	.02793	46	.03084
07	.01949	17	.02240	27	.02531	37	.02822	47	.03114
08	.01978	18	.02269	28	.02560	38	.02851	48	.03143
09	.02007	19	.02298	29	.02589	39	.02881	49	.03172
1 10	.02036	1 20	.02328	1 30	.02619	1 40	.02910	1 50	.03201

II. NOTING WHEN POLARIS AND ANOTHER STAR ARE IN THE SAME VERTICAL PLANE.

For places north of latitude 35°, the true meridian may be determined by taking advantage of the fact that two bright stars in the northern heavens cross the meridian on opposite sides of the pole only a few minutes before Polaris. These stars are the ones known as Zeta (ζ) Ursæ Majoris or Mizar and Delta (δ) Cassiopeiæ. Their positions in the constellations are shown in the accompanying diagram.

Select that one of the two stars which at the time of the year when observations are to be made passes the meridian below the pole. When the star passes the meridian above the pole it is too near the zenith to be used. Delta Cassiopeiæ is on the meridian below the pole at midnight about April 10, and is, therefore, the proper star to use at that date and for three months before and after. For the other six months of the year Zeta Ursæ Majoris will be the proper star to use. In the long days of June and July the

lower culmination of both stars occurs during daylight, so that the method can not be used.

Using the apparatus described under I, Observations of Polaris at Elongation, keep the peep sight in line with the plumb line and Polaris until the selected star also appears upon the plumb line. Carefully note the time when this occurs. Then, by moving the peep sight, continue to preserve its alignment with Polaris and the plumb line (paying no further attention to the other star). At the expiration of 12.5 minutes (in 1922) Polaris will be on the meridian and the peep sight and plumb line will then define a true north and south line, which may be permanently marked for future use. *For each year subsequent to 1922 the interval increases approximately half a minute.*

As the pole distance of Delta Cassiopeiæ is 35° and that of Zeta Ursæ Majoris is 40°, this method can not be used for the southern part of the United States where the stars are below the horizon at lower culmination.

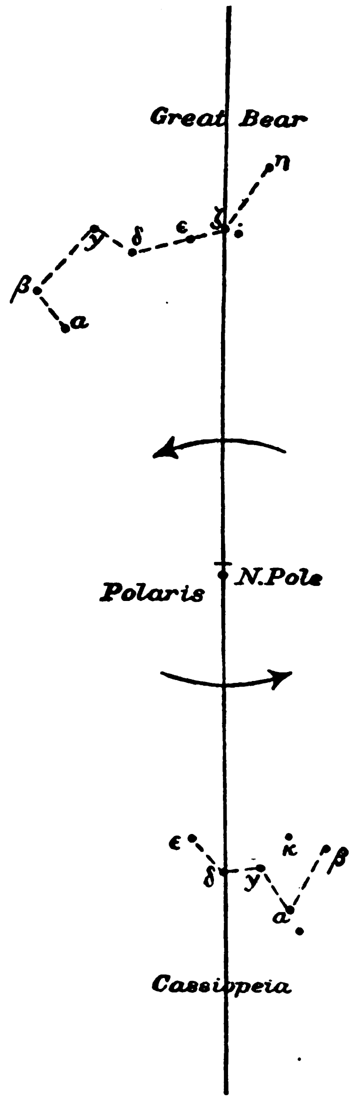

Diagram showing the principal stars of the constellations Cassiopeia and Great Bear (Ursa Major) with Delta Cassiopeiæ, Zeta Ursae Majoris, and Polaris on the meridian (represented by the straight line), Polaris being at lower culmination.

III. OBSERVATIONS OF POLARIS AT ELONGATION.

With a surveyor's transit the true meridian may be determined by observing Polaris at elongation as follows:

Select a station for observing which affords a good view of the northern sky and with the ground clear for at least 100 yards to the north.

If the station is to be used for determining the magnetic declination, care should be taken to have it well removed from electric car lines, buildings, and other possible sources of disturbance. If a meridian line is to be established for future use, the ends should be placed so that they may be protected from disturbance.

Mark the observing station in a suitable manner; for example, by a stone post with a drill hole in the top, set firmly in the ground.

About 30 minutes before the time of elongation of Polaris, derived from Table I, set up the transit with its vertical axis exactly over the station mark and carefully level the instrument. It is essential that the transverse axis of the telescope be horizontal. This should be tested in the daytime by pointing on the vertical edge of a house and

noting whether the vertical cross wire continues to coincide with the edge of the house as the telescope is turned in altitude.

Illuminate the cross wires by the light from a bull's-eye lantern or a pocket flashlight directed obliquely into the object end of the telescope by an assistant.

Point the telescope at the star and clamp the horizontal circle. Keep the star covered by the vertical cross wire by means of the tangent screw of the vernier plate, until a point is reached where it appears to move up or down along the wire without moving away from it, thus indicating that elongation has been reached.

Depress the telescope to the horizontal position; about 100 yards north of the instrument drive a stake and mark a point on its top exactly coincident with the vertical wire of the telescope. This will require a second assistant and light. Turn the vernier plate 180° and again set the vertical wire on the star, clamp the horizontal circle, depress the telescope, and mark another point on the stake. The point midway between the two marks, with the point under the instrument, will define on the ground the vertical plane through Polaris at its eastern or western elongation, as the case may be.

Near elongation the azimuth of the star changes very slowly, not more than 0′.1 in the 10 minutes before or after elongation in the United States, so that there is plenty of time to make the second pointing after reversal, if there is no unnecessary delay.

By daylight lay off the proper angle taken from Table II, to the east for western elongation and to the west for eastern elongation, and place a suitable marker to mark the north end of a meridian line of which the station marker will be the south end. The angle should be measured both before and after reversal, as in the case of the star.

IV. OBSERVATIONS OF POLARIS AT ANY HOUR.

The methods thus far described have the great advantage that an accurate knowledge of the time is not required, but they are not always convenient, as the elongation or culmination of Polaris does not always come at a convenient time for observing and the star may happen to be obscured just at that time.

The true meridian may be determined to the nearest minute of arc by observations of Polaris at any hour when the star is visible, provided the local mean time is known within 1 minute, as in the extreme case when Polaris is at culmination its azimuth changes 1 minute of arc in about 2 minutes in latitude 50°, and 1 minute of arc in about 3 minutes in latitude 20°. The standard time can usually be obtained at a telegraph office or directly by radio from the signals sent out from observatories. From this the local mean time may be derived by subtracting 4 minutes of time for every degree of longitude west of the standard meridian or adding 4 minutes for every degree east of the standard meridian.

The selection and marking of the observing station and the adjustment of the theodolite will be done as in the case of observations of Polaris at elongation. As the observations are to be made when the azimuth of the star is changing, it will be preferable to provide an azimuth mark, such as a light showing through a slit in a box, and make a series of measures of the angle between the mark and the star. The light used to illuminate the cross wires of the telescopes may be used also in reading the horizontal circle.

Begin by pointing on the mark and reading the horizontal circle. Point on the star, record the exact time and the reading of the circle. Turn the vernier plate 180° in azimuth and again point on the star, recording the time and circle reading as before. Finally, point on the mark again and read the circle. The number of pointings in a set may be increased or additional sets may be taken to secure greater accuracy. The azimuth of Polaris for the local mean time of observation will be derived from Table IV in the manner explained below.

The following example explains the use of the table and the derivation of the hour angle of Polaris:

Position, latitude 36° 20′ N., longitude 80° 07′.5 or 5^h 20^m 30^s W. of Greenwich.

	°	′	″	h.	m.	s.	
Time of observation, July 10, 1923, standard (75th meridian) mean time				8	52	40	p. m.
Reduction to local time				−	20	30	
Local mean time				8	32	10	
Reduction to sidereal time (Table III, Amer. Ephem.)				+	01	24	
Sidereal time mean noon, Greenwich, July 10, 1923				7	09	33	
Correction for longitude 5^h 20^m 30^s (Table III, Amer. Ephem.)				+	00	53	
Local sidereal time				15	44	00	
Apparent right ascension of Polaris, July 10, 1923				1	33	47	
Hour angle before upper culmination				9	49	47	
Declination for which Table IV applies	88	53	25				
Apparent declination, July 10, 1923	88	53	19				
Decrease in declination			06				
Azimuth from Table IV (interpolated)	0	44.0					
Correction for 6″ decrease in declination, Table V	+	0.1					
Computed azimuth	0	44.1 east of north.					

It is to be remembered that Polaris is east of the meridian for 12 hours before, and west of the meridian for 12 hours after, upper culmination.

Without the American Ephemeris the table may be conveniently used for obtaining the true meridian, in connection with Table I giving the approximate mean times of culminations of Polaris.

	°	′	″	h.	m.	s.	
Time of observation, July 10, 1923, standard (75th meridian) mean time				8	52	40	p. m.
Reduction to local mean time				−	20	30	
Local mean time				8	32	10	
Local mean time of upper culmination of Polaris (Table I and A)				18	20	18	
Mean time of observation before upper culmination				9	48	08	
Reduction to sidereal time				+	01	38	
Hour angle before upper culmination				9	49	46	
Declination for which Table IV applies	88	53	25				
Declination July 15, 1923	88	53	19				
Decrease in declination			06				
Azimuth from Table IV	0	44.0					
Correction for 6″ decrease in declination, Table V	+	0.1					
Computed azimuth	0	44.1 east of north.					

Tables are generally given in books on surveying for reducing mean solar to sidereal time, but for this computation it is near enough to consider the correction 10^s an hour, as the stars gain very nearly 4 minutes on the sun each day.

TABLE IV.—*Azimuth of Polaris at all hour angles.*

[Computed for declination 88° 53′ 25″. For hour angles 0^h to 12^h the star is west of north, and from 12^h to 24^h it is east of north.]

H.A. \ Lat.	10°	15°	20°	25°	30°	32°	34°	36°	Lat. / H.A.
h. m.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	h. m.
0 00	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	24 00
10	03.0	03.0	03.1	03.2	03.4	03.5	03.5	03.6	23 50
20	05.9	06.0	06.2	06.4	06.8	06.9	07.1	07.3	40
30	08.9	09.1	09.3	09.7	10.1	10.4	10.6	10.9	30
40	11.8	12.0	12.4	12.9	13.5	13.8	14.1	14.5	20
50	14.7	15.0	15.4	16.1	16.8	17.2	17.6	18.1	10
1 00	17.6	17.9	18.5	19.2	20.1	20.6	21.0	21.6	00
10	20.4	20.8	21.5	22.3	23.4	23.9	24.4	25.1	22 50
20	23.2	23.7	24.4	25.4	26.6	27.2	27.8	28.5	40
30	26.0	26.5	27.3	28.4	29.7	30.4	31.1	31.9	30
40	28.7	29.3	30.1	31.3	32.8	33.5	34.3	35.2	20
50	31.3	32.0	32.9	34.2	35.8	36.6	37.5	38.5	10
2 00	33.9	34.6	35.6	37.0	38.8	39.7	40.6	41.7	00
10	36.4	37.2	38.3	39.8	41.7	42.6	43.6	44.8	21 50
20	38.9	39.7	40.9	42.5	44.5	45.5	46.6	47.8	40
30	41.3	42.1	43.4	45.1	47.2	48.3	49.4	50.7	30
40	43.6	44.5	45.8	47.6	49.8	50.9	52.1	53.5	20
50	45.8	46.8	48.1	50.0	52.4	53.5	54.8	56.2	10
3 00	47.9	48.9	50.4	52.3	54.8	56.0	57.3	0 58.8	00
10	50.0	51.0	52.5	54.5	57.1	0 58.4	0 59.7	1 01.3	20 50
20	51.9	53.0	54.5	56.6	0 59.3	1 00.6	1 02.0	03.6	40
30	53.7	54.9	56.5	0 58.6	1 01.4	02.8	04.2	05.8	30
40	55.5	56.6	0 58.3	1 00.5	03.4	04.8	06.3	08.0	20
50	57.1	58.3	1 00.0	02.3	05.2	06.7	08.2	10.0	10
4 00	0 58.7	0 59.9	01.6	03.9	07.0	08.4	10.0	11.8	00
10	1 00.1	1 01.3	03.1	05.4	08.6	10.0	11.7	13.5	19 50
20	01.4	02.6	04.4	06.8	10.0	11.5	13.2	15.0	40
30	02.6	03.8	05.6	08.1	11.3	12.9	14.6	16.4	30
40	03.6	04.9	06.7	09.2	12.5	14.1	15.8	17.7	20
50	04.5	05.9	07.7	10.2	13.6	15.2	16.9	18.8	10
5 00	05.4	06.7	08.6	11.1	14.5	16.1	17.8	19.8	00
10	06.1	07.4	09.3	11.9	15.3	16.9	18.6	20.6	18 50
20	06.6	08.0	09.9	12.5	15.9	17.5	19.3	21.2	40
30	07.1	08.4	10.3	12.9	16.4	18.0	19.8	21.7	30
40	07.4	08.7	10.6	13.2	16.7	18.3	20.1	22.1	20
50	07.6	08.9	10.8	13.4	16.9	18.5	20.3	22.3	10
6 00	07.6	08.9	10.8	13.5	16.9	18.5	20.3	22.3	00
10	07.5	08.8	10.7	13.4	16.8	18.4	20.2	22.2	17 50
20	07.3	08.6	10.5	13.1	16.5	18.1	19.9	21.9	40
30	07.0	08.3	10.2	12.7	16.1	17.7	19.5	21.4	30
40	06.5	07.8	09.7	12.2	15.6	17.2	18.9	20.8	20
50	05.9	07.2	09.1	11.6	14.9	16.5	18.2	20.1	10
7 00	05.2	06.5	08.3	10.8	14.1	15.6	17.3	19.2	00
10	04.4	05.6	07.4	09.9	13.1	14.6	16.3	18.2	16 50
20	03.5	04.7	06.4	08.8	12.0	13.5	15.1	17.0	40
30	02.4	03.6	05.3	07.6	10.7	12.2	13.8	15.6	30
40	1 01.2	02.3	04.0	06.3	09.3	10.8	12.4	14.1	20
50	0 59.9	1 01.0	02.6	04.9	07.8	09.3	10.8	12.5	10
8 00	58.5	59.5	1 01.1	03.3	06.2	07.6	09.1	10.8	00
10	56.9	58.0	0 59.5	1 01.7	04.5	05.8	07.3	08.9	15 50
20	55.3	56.3	57.8	0 59.9	02.6	03.9	05.3	06.9	40
30	53.5	54.5	56.0	58.0	1 00.6	1 01.8	03.2	04.7	30
40	51.7	52.6	54.0	55.9	0 58.5	0 59.7	1 01.0	02.5	20
50	49.7	50.6	52.0	53.8	56.2	57.4	58.7	1 00.1	10
9 00	47.7	48.6	49.8	51.6	53.9	55.0	56.3	0 57.6	00
10	45.6	46.4	47.6	49.3	51.5	52.6	53.7	55.0	14 50
20	43.3	44.1	45.3	46.9	49.0	50.0	51.1	52.3	40
30	41.0	41.8	42.9	44.4	46.4	47.3	48.4	49.5	30
40	38.7	39.4	40.4	41.8	43.7	44.6	45.6	46.7	20
50	36.2	36.9	37.8	39.2	40.9	41.8	42.7	43.7	10
10 00	33.7	34.3	35.2	36.5	38.1	38.9	39.7	40.6	00
10	31.1	31.7	32.5	33.6	35.2	35.9	36.6	37.5	13 50
20	28.5	29.0	29.7	30.8	32.2	32.8	33.5	34.3	40
30	25.8	26.3	26.9	27.9	29.1	29.7	30.4	31.1	30
40	23.1	23.5	24.1	24.9	26.0	26.5	27.1	27.8	20
50	20.3	20.6	21.2	21.9	22.9	23.3	23.8	24.4	10
11 00	17.5	17.7	18.2	18.8	19.7	20.1	20.5	21.0	00
10	14.6	14.8	15.2	15.8	16.5	16.8	17.2	17.6	12 50
20	11.7	11.9	12.2	12.6	13.2	13.5	13.8	14.1	40
30	08.8	08.9	09.2	09.5	09.9	10.1	10.3	10.6	30
40	05.9	06.0	06.1	06.3	06.6	06.7	06.9	07.1	20
50	02.9	03.0	03.1	03.2	03.3	03.4	03.5	03.5	10
12 00	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	00

TABLE IV.—*Azimuth of Polaris at all hour angles*—Continued.

H.A. h.	H.A. m.	36°	38°	40°	42°	44°	46°	48°	50°	H.A. h.	H.A. m.
		° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′		
0	00	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	24	00
	10	03.6	03.7	03.9	04.0	04.1	04.3	04.4	04.6	23	50
	20	07.3	07.5	07.7	07.9	08.2	08.5	08.9	09.2		40
	30	10.9	11.2	11.5	11.9	12.3	12.8	13.3	13.8		30
	40	14.5	14.9	15.3	15.8	16.4	17.0	17.7	18.4		20
	50	18.1	18.6	19.1	19.7	20.4	21.2	22.0	22.9		10
1	00	21.6	22.2	22.9	23.6	24.4	25.3	26.3	27.4		00
	10	25.1	25.8	26.6	27.4	28.3	29.4	30.5	31.8	22	50
	20	28.5	29.3	30.2	31.2	32.2	33.4	34.7	36.2		40
	30	31.9	32.8	33.8	34.9	36.0	37.4	38.8	40.5		30
	40	35.2	36.2	37.3	38.5	39.8	41.3	42.9	44.7		20
	50	38.5	39.5	40.7	42.0	43.5	45.1	46.8	48.8		10
2	00	41.7	42.8	44.1	45.5	47.0	48.8	50.7	52.8		00
	10	44.8	46.0	47.4	48.9	50.5	52.4	54.5	0 56.7	21	50
	20	47.8	49.1	50.5	52.1	53.9	55.9	0 58.1	1 00.5		40
	30	50.7	52.1	53.6	55.3	0 57.2	0 59.3	1 01.6	04.2		30
	40	53.5	55.0	56.6	0 58.4	1 00.4	1 02.6	05.0	07.8		20
	50	56.2	0 57.7	0 59.4	1 01.3	03.4	05.7	08.3	11.2		10
3	00	0 58.8	1 00.4	1 02.2	04.1	06.3	08.7	11.4	14.5		00
	10	1 01.3	02.9	04.8	06.8	09.1	11.6	14.4	17.6	20	50
	20	03.6	05.3	07.3	09.4	11.8	14.4	17.3	20.6		40
	30	05.8	07.6	09.6	11.8	14.3	17.0	20.0	23.4		30
	40	08.0	09.8	11.9	14.1	16.6	19.4	22.5	26.0		20
	50	10.0	11.8	14.0	16.3	18.8	21.7	24.9	28.4		10
4	00	11.8	13.7	15.9	18.3	20.9	23.8	27.1	30.7		00
	10	13.5	15.5	17.7	20.1	22.8	25.8	29.1	32.8	19	50
	20	15.0	17.1	19.3	21.8	24.5	27.6	31.0	34.8		40
	30	16.4	18.5	20.8	23.3	26.1	29.2	32.7	36.5		30
	40	17.7	19.8	22.1	24.7	27.5	30.7	34.2	38.1		20
	50	18.8	20.9	23.3	25.9	28.8	32.0	35.5	39.5		10
5	00	19.8	21.9	24.3	26.9	29.8	33.1	36.6	40.6		00
	10	20.6	22.7	25.1	27.8	30.7	34.0	37.6	41.6	18	50
	20	21.2	23.4	25.8	28.5	31.4	34.7	38.3	42.4		40
	30	21.7	23.9	26.3	29.0	32.0	35.3	38.9	43.0		30
	40	22.1	24.3	26.7	29.4	32.4	35.6	39.3	43.4		20
	50	22.3	24.5	26.9	29.6	32.5	35.8	39.5	43.6		10
6	00	22.3	24.5	26.9	29.6	32.5	35.8	39.5	43.6		00
	10	22.2	24.4	26.8	29.4	32.4	35.7	39.3	43.4	17	50
	20	21.9	24.1	26.5	29.1	32.1	35.3	38.9	43.0		40
	30	21.4	23.6	26.0	28.6	31.5	34.8	38.4	42.4		30
	40	20.8	23.0	25.4	28.0	30.8	34.1	37.6	41.6		20
	50	20.1	22.2	24.6	27.2	30.0	33.2	36.7	40.6		10
7	00	19.2	21.3	23.6	26.2	29.0	32.1	35.6	39.4		00
	10	18.2	20.2	22.5	25.0	27.8	30.9	34.3	38.1	16	50
	20	17.0	19.0	21.2	23.7	26.4	29.5	32.8	36.6		40
	30	15.6	17.6	19.8	22.2	24.9	27.9	31.2	34.9		30
	40	14.1	16.1	18.2	20.6	23.2	26.1	29.4	33.0		20
	50	12.5	14.4	16.5	18.8	21.4	24.2	27.4	30.9		10
8	00	10.8	12.6	14.7	16.9	19.4	22.2	25.3	28.7		00
	10	08.9	10.7	12.7	14.9	17.3	20.0	23.0	26.3	15	50
	20	06.9	08.6	10.5	12.7	15.0	17.6	20.5	23.7		40
	30	04.7	06.4	08.3	10.3	12.6	15.1	17.9	21.0		30
	40	02.5	04.1	05.9	07.9	10.1	12.5	15.2	18.2		20
	50	1 00.1	1 01.7	03.4	05.3	07.4	09.7	12.3	15.2		10
9	00	0 57.6	0 59.1	1 00.8	1 02.6	04.6	06.8	09.3	12.1		00
	10	55.0	56.5	0 58.0	0 59.8	1 01.7	03.8	06.2	08.8	14	50
	20	52.3	53.7	55.2	56.8	0 58.6	1 00.7	1 02.9	05.4		40
	30	49.5	50.8	52.2	53.8	55.5	0 57.4	0 59.6	1 01.9		30
	40	46.7	47.9	49.2	50.7	52.3	54.1	56.1	0 58.3		20
	50	43.7	44.8	46.1	47.4	48.9	50.6	52.5	54.6		10
10	00	40.6	41.7	42.9	44.1	45.5	47.1	48.8	50.8		00
	10	37.5	38.5	39.6	40.7	42.0	43.5	45.1	46.9	13	50
	20	34.3	35.2	36.2	37.3	38.5	39.8	41.2	42.9		40
	30	31.1	31.9	32.8	33.8	34.8	36.0	37.3	38.8		30
	40	27.8	28.5	29.3	30.2	31.0	32.2	33.3	34.7		20
	50	24.4	25.0	25.7	26.5	27.3	28.3	29.3	30.5		10
11	00	21.0	21.5	22.1	22.8	23.5	24.3	25.2	26.2		00
	10	17.6	18.0	18.5	19.1	19.7	20.3	21.1	21.9	12	50
	20	14.1	14.4	14.8	15.3	15.8	16.3	16.9	17.6		40
	30	10.6	10.9	11.2	11.5	11.8	12.3	12.7	13.2		30
	40	07.1	07.3	07.5	07.7	07.9	08.2	08.5	08.8		20
	50	03.5	03.6	03.7	03.8	04.0	04.1	04.2	04.4		10
12	00	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0		00

The above table is taken from the American Ephemeris for 1922, and was computed for a declination of Polaris of 88° 53′ 25″. For other declinations the corrections given in Table V should be applied. The correction is very nearly proportional to the azimuth and amounts to a decrease of 0′.9 in azimuth for an increase of declination of 1′ for an azimuth of 60′. The above declination is very nearly a mean value for the year 1922, the declination varying during the year as follows:

	°	′	″		°	′	″
January 15..........	88	53	35	July 15..........	88	53	03
February 15..........		53	33	August 15..........		53	07
March 15..........		53	26	September 15..........		53	16
April 15..........		53	17	October 15..........		53	27
May 15..........		53	08	November 15..........		53	38
June 15..........		53	03	December 15..........		53	47

The annual increase in declination of Polaris is about 16″.

TABLE V.—*Correction to tabular azimuths for other declinations.*

Azimuth................	0′	20′	40′	60′	80′	100′	120′
Declination: ° ′ ″	′	′	′	′	′	′	′
88 53 25................	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53 30................	0.0	0.0	−0.1	−0.1	−0.1	−0.1	−0.2
53 35................	0.0	0.0	0.1	0.2	0.2	0.3	0.3
53 40................	0.0	−0.1	0.2	0.2	0.3	0.4	0.5
53 45................	0.0	0.1	0.2	0.3	0.4	0.5	0.6
53 50................	0.0	0.1	0.3	0.4	0.5	0.6	0.8
53 55................	0.0	0.2	0.3	0.5	0.6	0.8	0.9
54 00................	0.0	0.2	0.4	0.5	0.7	0.9	1.1
54 05................	0.0	0.2	0.4	0.6	0.8	1.0	1.2
54 10................	0.0	0.2	0.5	0.7	0.9	1.1	1.4
54 15................	0.0	0.2	0.5	0.8	1.0	1.3	1.5
54 20................	0.0	0.3	0.6	0.8	1.1	1.4	1.7
54 25................	0.0	−0.3	−0.6	−0.9	−1.2	−1.5	−1.8

V. OBSERVATIONS OF THE SUN.

The following method is the one usually employed to determine the true meridian in connection with the magnetic observations of the U. S. Coast and Geodetic Survey. It involves more computing than those already described, but is more convenient in that it is available for use during daylight when the magnetic observations are in progress. In connection with the time signals sent out by telegraph from observatories it furnishes the means also of determining approximately the longitude of the place of observation. It requires a theodolite with graduated vertical circle and a prismatic eyepiece for observing the sun, and a well-regulated timepiece. The observations at a place usually consist of four independent sets of observations, two in the morning and two in the afternoon, each set consisting of four pointings on the sun and two pointings on a reference mark, symmetrically arranged as in the following example. For each pointing on the sun the time is noted, and both horizontal and vertical circles are read. Observations are made from two to four hours from noon, and at nearly the same altitudes morning and afternoon. The reference mark should be a well-defined object nearly in the horizon and at least 100 yards distant.

The instrument used in the following observations has a glass diaphragm on which is ruled one horizontal and one vertical line. The symbols in the first column indicate the limbs of the sun which were brought tangent to the lines of the diaphragm at the recorded time. The vertical circle is so graduated that it gives altitudes in one position and zenith distances in the other. The readings in the latter case have been subtracted from 90° when filling in the last column. The verniers allow readings on the horizontal and on the vertical circle to be made to minutes, half minutes being estimated.

Observations of sun for azimuth and time.

A. M. OBSERVATIONS.

[Station, Paducah, Ky.; theodolite of Mag'r No. 19; chronometer, Bond No. 175; date, Tuesday, July 2, 1901; observer, W. W.; temperature, 32°.2.]

Sun's limb.	V. C.	Chronometer time.	Horizontal circle. A	Horizontal circle. B	Horizontal circle. Mean.	Vertical circle. A	Vertical circle. B	Vertical circle. Mean.
			° ′	′	° ′	° ′	′	° ′
	R	Mark	352 39.5	37.5	352 38.5			
	L		172 37.0	36.0	36.5			
		h. m. s.						
☉	L	9 35 15	291 41.0	39.5	111 40.2	44 17.0	18.0	44 17.50
☉	L	36 10	291 49.5	48.5	111 49.0	44 29.0	29.0	44 29.00
☉	R	37 40	112 47.0	44.0	112 45.5	44 48.0	49.5	45 11.25
☉	R	38 47	112 57.0	56.0	112.56.5	44.35.0	36.5	45 24.25
Mean		9 36 58.0			112 17.8			44 50.50
						Refr. and Par		−0.78
☉	R	9 39 46	113 07.0	05.5	113 06.2	44 23.0	25.0	45 36.00
☉	R	40 49	113 16.0	18.0	113 17.0	44 10.5	12.0	45 48.75
☉	L	42 20	292 50.0	48.0	112 49.0	45 41.5	42.0	45 41.75
☉	L	43 24	292 60.0	58.5	112 59.2	45 54.0	55.0	45 54.50
Mean		9 41 34.8			113 02.8			45 45.25
						Refr. and par		−.76
	L	Mark	172 38.0	37.5	352 37.8			
	R		352 40.0	38.0	39.0			
					352 37.9			

P. M. OBSERVATIONS.

[Station, Paducah, Ky.; theodolite of Mag'r No. 19; chronometer, Bond No. 175; date, Tuesday, July 2, 1901; observer, W. W.; temperature, 36°.8.]

Sun's limb.	V. C.	Chronometer time.	Horizontal circle. A	Horizontal circle. B	Horizontal circle. Mean.	Vertical circle. A	Vertical circle. B	Vertical circle. Mean.
	R	Mark	112 20.5	19.0	112 19.8			
	L		292 20.5	19.0	19.8			
		h. m. s.						
☉	L	4 21 28	226 01.0	01.0	46 01.0	44 13.5	14.0	44 13.75
☉	L	22 26	226 10.0	11.0	46 10.5	44 02.0	03.0	44 02.50
☉	R	23 45	45 32.0	35.0	45 33.5	45 49.0	47.0	44 12.00
☉	R	25 04	45 45.0	48.0	45 46.5	46 03.0	04.5	43 56.25
Mean		4 23 10.8			45 52.9			44 06.12
						Refr. and par		−.79
☉	R	4 34 24	47 17.0	14.5	47 15.8	47 53.0	56.0	42 05.50
☉	R	35 36	47 25.0	27.0	47 26.0	48 07.5	10.0	41 51.25
☉	L	37 12	228 28.0	26.0	48 27.0	41 07.0	08.0	41 07.50
☉	L	38 19	228 38.0	37.5	48 37.8	40 53.0	53.5	40 53.25
Mean		4 36 22.8			47 56.6			41 29.38
						Refr. and par		−.89
	L	Mark	292 21.0	19.5	112 20.2			
	R		112 21.0	19.5	20.2			
					112 20.0			

The formulas used in computing the azimuth and local mean time from observations of the sun made in the manner just described are the following:

$$\operatorname{ctn}^2 \tfrac{1}{2} A = \frac{\sin (s-\phi) \sin (s-h)}{\cos s \cos (s-p)}$$

$$= \sec s \sec (s-p) \sin (s-h) \sin (s-\phi)$$

$$\tan \tfrac{1}{2} t = \frac{\sin (s-h) \sec (s-p)}{\operatorname{ctn} \tfrac{1}{2} A}$$

A = azimuth of sun, east of south in the morning, west of south in the afternoon.
ϕ = latitude of the place.
h = altitude of the sun corrected for refraction and parallax in altitude.
p = Polar distance of the sun, at the time of observation, taken from the American Nautical Almanac.
$s = \tfrac{1}{2} (h+\phi+p)$.
t = The hour angle of the sun or apparent time of observation expressed in arc.

By combining the azimuth of the sun with the angle between the sun and mark, the azimuth of the mark may be obtained. This is counted from 0 to 360° from south around by west. When the azimuth of the mark is known the true meridian may be laid off at any time by turning off the proper angle.

The apparent time of observation must be corrected for equation of time (taken from the Nautical Almanac), in order to obtain the local mean time. The following is a convenient form of computation:

Computation of azimuth and longitude.

Date.	Tuesday, July 2, 1901.			
	° ′	° ′	° ′	° ′
h	44 49.7	45 44.5	44 05.3	41 28.5
ϕ	37 03.6	37 03.6	37 03.6	37 03.6
p	66 55.5	66 55.5	66 56.7	66 56.8
$2s$	148 48.8	149 43.6	148 05.6	145 28.9
s	74 24.4	74 51.8	74 02.8	72 44.4
$s-p$	7 28.9	7 56.3	7 06.1	5 47.6
$s-h$	29 34.7	29 07.3	29 57.5	31 15.9
$s-\phi$	37 20.8	37 48.2	36 59.2	35 40.8
log sec s	0.57056	0.58316	0.56090	0.52767
log sec $(s-p)$	0.00371	0.00418	0.00334	0.00222
log sin $(s-h)$	9.69339	9.68723	9.69842	9.71516
log sin $(s-\phi)$	9.78293	9.78743	9.77933	9,76586
log ctn² ½ A	0.05059	0.06200	0.04199	0.01091
log ctn ½ A	0.02530	0.03100	0.02100	0.00546
	° ′	° ′	° ′	° ′
A from South	86 39.8	85 54.8	87 13.8	89 16.8
Circle reads	112 17.8	113 02.8	45 52.9	47 56.6
S. Mer. reads	198 57.6	198 57.6	318 39.1	318 39.8
Mark reads	352 37.9	352 37.9	112 20.0	112 20.0
Az. of Mark	153 40.3	153 40.3	153 40.9	153 40.2
Mean	153 40.4	... .	... .	... .
log sec $(s-p)$ sin $(s-h)$	9.69710	9.69141	9.70176	9.71738
log tan ½ t	9.67180	9.66041	9.68076	9.71192
t in arc	50° 19′ 00″	49° 10′ 12″	51° 13′ 57″	54° 30′ 32″
	h. m. s.	h. m. s.	h. m. s.	h. m. s.
t	−3 21 16.0	−3 16 40.8	3 24 55.8	3 38 02.1
E	3 40.2	3 40.2	3 43.4	3 43.5
Local M. T.	8 42 24.2	8 46 59.4	3 28 39.2	3 41 45.6
Chron. time	9 36 58.0	9 41 34.8	4 23 10.8	4 36 22.8
Δt on L. M. T	−54 33.8	−54 35.4	−54 31.6	−54 37.2
Δt on 75 M. T	−6.8	−6.8	−6.9	−6.9
$\Delta\lambda$	54 27.0	54 28.6	54 24.7	54 30.3
Mean	54 27.6	−13° 36′.9	λ=	88° 36′.9

For computing observations of this type one requires a five-place table of logarithms of trigonometrical functions and the American Nautical Almanac, which gives the sun's apparent declination and the equation of time. For correcting the observed altitude of the sun for parallax and refraction the following table has been prepared, giving the combined correction for different altitudes and temperatures, to be subtracted from the observed altitude:

TABLE VI.—*Correction for parallax and refraction.*

Apparent altitude (degrees).	Temperature, centigrade.						
	−10°	0°	+10°	+20°	+30°	+40°	+50°
	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″
0	36 36	35 15	34 00	32 50	31 45	30 45	29 50
1	26 10	25 12	24 18	23 28	22 42	22 00	21 20
2	19 35	18 51	18 11	17 34	16 59	16 26	15 57
3	15 20	14 46	14 15	13 46	13 18	12 53	12 30
4	12 31	12 03	11 37	11 13	10 50	10 30	10 11
5	10 29	10 05	9 44	9 24	9 05	8 48	8 32
6	8 59	8 38	8 20	8 03	7 47	7 32	7 18
7	7 49	7 31	7 15	7 00	6 46	6 33	6 21
8	6 55	6 39	6 25	6 12	5 59	5 48	5 37
9	6 11	5 57	5 44	5 32	5 21	5 11	5 01
10	5 34	5 22	5 10	4 59	4 49	4 39	4 30
11	5 04	4 52	4 42	4 32	4 23	4 14	4 06
12	4 39	4 29	4 19	4 10	4 01	3 53	3 46
13	4 17	4 07	3 58	3 50	3 42	3 35	3 28
14	3 58	3 49	3 41	3 33	3 26	3 19	3 13
15	3 42	3 34	3 26	3 19	3 12	3 06	3 00
16	3 27	3 19	3 12	3 05	2 59	2 53	2 47
17	3 14	3 07	3 00	2 54	2 48	2 42	2 37
18	3 02	2 55	2 49	2 43	2 37	2 32	2 27
19	2 52	2 45	2 39	2 33	2 28	2 23	2 19
20	2 42	2 36	2 30	2 25	2 20	2 15	2 11
21	2 33	2 27	2 22	2 17	2 12	2 08	2 04
22	2 26	2 20	2 15	2 10	2 06	2 02	1 58
23	2 18	2 13	2 08	2 03	1 59	1 55	1 51
24	2 12	2 07	2 02	1 58	1 54	1 50	1 46
25	2 05	2 00	1 56	1 52	1 48	1 44	1 41
26	2 00	1 55	1 51	1 47	1 43	1 39	1 36
27	1 55	1 50	1 46	1 42	1 38	1 35	1 32
28	1 49	1 45	1 41	1 37	1 34	1 31	1 28
29	1 45	1 41	1 37	1 33	1 30	1 27	1 24
30	1 41	1 37	1 33	1 30	1 26	1 23	1 21
32	1 33	1 29	1 26	1 23	1 19	1 17	1 15
34	1 26	1 22	1 19	1 16	1 13	1 11	1 09
36	1 19	1 16	1 13	1 10	1 08	1 05	1 03
38	1 13	1 10	1 07	1 04	1 02	1 00	0 58
40	1 08	1 05	1 02	1 00	0 58	0 56	0 54
42	1 03	1 00	0 58	0 56	0 54	0 52	0 50
44	0 59	0 56	0 54	0 52	0 50	0 48	0 47
46	0 54	0 52	0 50	0 48	0 46	0 45	0 43
48	0 51	0 49	0 47	0 45	0 44	0 42	0 41
50	0 47	0 45	0 43	0 41	0 40	0 38	0 37
55	0 39	0 37	0 36	0 35	0 33	0 32	0 31
60	0 32	0 30	0 29	0 28	0 27	0 26	0 25
65	0 25	0 24	0 23	0 22	0 21	0 20	0 20
70	0 20	0 19	0 18	0 17	0 17	0 16	0 15
75	0 14	0 14	0 13	0 12	0 12	0 12	0 11
80	0 10	0 09	0 09	0 09	0 08	0 08	0 08
85	0 04	0 04	0 04	0 04	0 04	0 04	0 03
90	0 00	0 00	0 00	0 00	0 00	0 00	0 00

DETERMINATION OF THE MAGNETIC DECLINATION.

When the magnetic declination is to be determined with an ordinary compass or the needle of a surveyor's transit, care should be taken to have the instrument in good adjustment and readings should be taken on both ends of the needle so as to eliminate outstanding error of eccentricity, whether due to the pivot not being exactly over the center of the graduated circle, to the needle being bent, or to the line of sight not passing through the zero points of the circle. Points requiring attention are:

Peep sights.—See that they are vertical by pointing on a plumb line or the vertical edge of a building.

Needle.—A sluggish or irregular motion may be due to a damaged jewel, a dull pivot, or loss of magnetism.

Balance of needle.—The balancing weight should be shifted if necessary, so that the needle will be horizontal.

Level.—The bubble should be adjusted to remain in the center throughout an entire revolution of the instrument.

Knives and other iron or steel objects should be removed from the person of the observer.

Observations should be made on several days if possible. The best time of day for observing is ordinarily toward the evening, about 5 or 6 o'clock, as the declination at that time is near its mean value for the day and is nearly stationary. The mean value of declination also occurs between 10 and 11 a. m. usually, but the change at that time is rapid. Observations made at other times of the day may be corrected approximately for diurnal variation by means of the table on page 16.

The observations on any one day should cover a period of half an hour (preferably more), with readings at intervals of 5 or 10 minutes. The time should be recorded for each set of readings, together with the date, weather, and the kind of time the observer's watch was keeping.

It is important that the surveyor should know the constant correction of his instrument, which may amount to 15 minutes or even more. This can be determined by observing with it at one of the magnetic stations established by this bureau. The difference between the declination for such a station furnished by this office and the value determined with the surveyor's compass represents the correction which must be applied to results with the latter.

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